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SURGICAL LESSONS

OF THE

GREAT WAR

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SURGICAL LESSONS

OF THE

GREAT WAR

MOTTO:

"Pecowsic"

BY

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THE Trustees of the Fiske Fund, at the annual meeting of the Rhode Island Medical Society, held at Providence, June 3, 1920, announced that they had awarded a premium of two hundred dollars to an essay on "Surgical Lessons of the Great War", bearing the motto:

"Pecowsic"

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SURGICAL LESSONS OF THE GREAT WAR

Early in 1914 the Medical Corps of every European army was serenely confident of its ability to deal most competently with battle casualties, and rightly so. Through actual experience and keen observation in the Russo-Japanese, Boer, and Balkan Wars the effect of missiles on human tissues was well known and understood. The character of war wounds and their treatment had been thoroughly studied and completely mastered. Advances in surgical knowledge and skill had not only made possible the prevention of infection with its consequent delayed healing, disfigurement, and mortality, but had also so perfected operative technique that regions of the body previously deemed inaccessible could be entered with impunity. New devices, compact and portable, made it feasible to operate aseptically in the open field far from established hospitals. The organization and training of the Medical Corps had been brought to a degree of perfection never before equalled. Transportation facilities for the wounded, especially the motor ambulance, were so efficient, rapid, and elastic that it was felt unlimited casualties could be promptly handled without confusion or congestion.

In the first weeks of the great war the Medical Departments functioned smoothly. The

character of the wounds, for the most part due to small, sharp pointed, high velocity bullets, were much as expected. First aid aseptic dressings held off infection surprisingly well; as low as 20 per cent of the wounds became infected. For the most part casualties were rapidly evacuated to the rear, and not until they reached base hospitals were they subjected, except for dire emergencies, to operative procedures. Even those operated at the front were, according to prearranged program, sent comfortably to the rear at the earliest possible moment.

With the definite check of the German advance, however, and the resultant dead-lock from Switzerland to the sea, the character of warfare was vastly changed. Open fighting, swift maneuvering, and frequent change of positions gave way to the fixed routine of immobile trench conflict. The rifle and bayonet gave way to artillery and bombs; the free open life in the field was bartered away for a cramped and crowded existence in and under the earth. The whole scheme of warfare had to be radically changed to meet unforeseen conditions; every military department had to be reorganized and to a large extent re-equipped with new devices to cope with unsuspected difficulties. Many well tried methods that had withstood the test of previous wars proved to be utterly worthless and had to be ruthlessly scrapped. Probably no department of the army was harder hit than the medical; for the great principle on which its work was primarily based was proved in a few weeks to

be not only useless, but to some extent even harmful, when applied to conditions incident to trench warfare. Asepsis fell down.

Infected Wounds.

In direct contrast to the wounds early in the war, those received in the trenches developed infection almost universally. That such was the rule in spite of painstaking aseptic technique from the moment the soldier's sterile first aid dressing was applied immediately after the wound was inflicted, was such a staggering blow that surgeons were loathe to believe that the principle was at fault. Unjust criticism was showered on the front line dressers who were accused of breaks in technique. But as time went on and infection of wounds continued rife, the unavoidable conclusion was accepted. That the Medical Corps did not become immediately and utterly demoralized when its sheet anchor gave way bespeaks the character and ability of its personnel. True to its traditions the medical profession met the problem and conquered.

The causes of infection were not hard to determine. The preponderance of artillery of large calibre using high explosive shells changed entirely the character of the wounds. Instead of the small, clean cut, punctured rifle bullet wound that not infrequently simply penetrated tissue, there presented for treatment savagely lacerated wounds of large extent generally concealing in their depths jagged pieces of missile and bits of clothing. All the wounds resembled

the torn and gaping wounds of exit made by rifle bullets that encountered bone or that were inflicted within the range when the bullet's explosive effect was paramount. Furthermore the destruction of tissue from high explosives extended far beyond the visible limits of the wound that often had no exit. Muscle and fascia under normal looking skin surrounding the wound was bruised, battered, even dead, robbed of all power of natural resistance. Thus the character of the wounds, large and lacerated, harboring foreign bodies, and surrounded by an area of devitalized tissue, was an invitation to infection that was quickly accepted.

The mode of living imposed by trench conflict but further encouraged infection. Soldiers lived below the surface of the earth under crowded, unsanitary conditions. The trenches themselves were always wet, frequently mere mud holes. For hours at a time the men were drenched and cold which led to universal respiratory infections. The filthy dug-outs swarmed with vermin that preyed on the men and inoculated them with debilitating diseases. Bodily cleanliness and frequent changes of clothing were impossible. Skin and apparel carried into wounds were grossly infected with many varieties of bacteria. Every aspect of the existence endured in the trenches led directly or indirectly to debilitation, sapped vitality, and lowered natural resistance to infection.

Evacuation of casualties from the front line was exceedingly difficult. Not only were the

trenches themselves actively bombarded but the entire back areas, especially lines of communication were subjected to frequent, regular, and devastating fire. For the most part, therefore, the wounded had to be moved at night. It was not at all unusual for the wounded to lie for hours, frequently even for days, where they fell, wet and cold, without proper treatment. The first stage of the journey to the rear had to be taken in men-borne stretchers, slowly, over uneven and precarious paths, through winding trenches, time consuming trips that unmercifully jolted and tortured shattered bodies beyond endurance. Pain, cold, hunger, and thirst increased every hour; and surreptitiously infection ripened and spread with each minute's delay. On the other hand once casualties had been brought to areas of comparative safety they were subjected to repeated transfers from hospital to hospital before reaching their final station. The movement was ever toward the home area on the conviction that prompt removal of the wounded to home surroundings was in itself a powerful psychological stimulus to speedy recovery. The conviction, however, proved to be erroneous. Many wounds, even after prompt and thorough treatment, and showing every indication of rapid aseptic healing, reached base hospitals a few days later in a deplorable state of rife sepsis which could be explained only by the premature evacuation.

Wide, savage wounds; unsanitary and exhausting conditions of living; and delay in treat-

ment, all contributed generously to the development of surgical shock. Often the patient's condition was so critical that surgical intervention in the wound had to be postponed, or at least limited to an unsatisfactory minimum, in order to snatch from impending death by shock a man who later succumbed because of the delay to gross infection. It was ever a vicious circle.

The soil of the lengthy battle front had for centuries been intensively cultivated and generously fertilized until its upper layer teemed with bacteria, more especially anaerobes. This was the soil that smirched the bodies and caked the clothing of the soldiers, whence it was carried into the depths of wounds and lodged in battered tissue bereft of all natural power to resist invasion. There the micro-organisms found ideal homes where they flourished and multiplied.

Finally the huge numbers in the contending armies, far exceeding all past experience, at times flooded available hospitals and overwhelmed local facilities. It was often physically impossible, therefore, to give prompt and thorough treatment to all cases; the greatest good of the greatest number had to be the rule. A single case, even if urgent, had to wait, if it would absorb time in which a dozen others, equally urgent but requiring less time, could be cared for. Time spent on moribund cases was time wasted.

Such were the conditions that had to be accepted; the problem of the Medical Corps was to produce results in spite of them. Infection

was the dominating evil; therefore, the prevention of infection became the crying need. Everything was subordinated to that one purpose; the measure of every procedure, of every invention, of every act, was whether or not it prevented infection. If it did all good and well; if not, it was ruthlessly discarded.

General measures that had to do with the health and comfort of the men were promptly enforced. Shorter hours of duty in the front line trenches, still further ameliorated by frequent reliefs, furnished helpful periods of rest, afforded welcome opportunities for drying and changing clothing, and best of all allowed more regular distribution of warm food. There were times of course when this happy routine was rudely interrupted by enemy activity, but for the most part, especially in the long stretches of so-called quiet sectors, it was preserved. Gradually engineers changed and added to the first hastily dug trenches until they became more roomy and livable. Drainage measures were instituted, and where the soil or location was less favorable pumps or other devices for removing the excess of water were installed. Delousing stations and bathing facilities were set up far in the rear at so-called rest depots where regularly whole regiments at a time were allowed for several days absolute rest from duty and forced to clean up. First aid and regimental dressing stations were pushed close to the front line trenches, and field and evacuation hospitals were brought farther forward for the purpose of rendering earlier

surgical attention. The kind of treatment afforded the wounded in the earliest stages is reflected in the whole course of their subsequent illness; and no amount of surgical skill can undo an error previously committed. Transportation of the wounded was speeded up and so well correlated among separate units that not infrequently casualties demanding urgent operation reached the proper hospital within a few hours. Motor ambulances alone made this possible. In fact, the motor ambulance is the very foundation on which surgery at the front is based. On the other hand premature evacuation of patients already operated was retarded. Unless the wounded could be safely held at the place of operation for a reasonable length of time, it was best to evacuate them unoperated. The delay occasioned by the postponement of definitive surgery was far less injurious than the damage done to a healing wound by the exigencies of a trying journey. Every effort was made, therefore, through early classification of cases to make the first transfer the final one, or at least to hold operated cases at the place of operation for about ten days. Special shock teams and rooms were established at designated points where special treatment could be promptly and vigorously carried out. The urgent but time consuming cases that had to wait when the rush was greatest came to be better handled through the creation of observation wards. There doubtful and postponed cases were segregated. If mixed with other wounded men these cases were liable to

be overlooked. Each man was tagged with the name of a surgeon whose duty it was to visit all his observation cases at stated intervals to the end that he not only might not forget them, but also that he might be regularly made cognizant of their condition. In this manner cases were often sandwiched in between operations and lives saved that would otherwise have been lost. All these measures aimed at conserving human vitality and enhancing, or at least preserving, natural resistance against disease, to the end that the individual's own defenses against infection should be brought to the point of maximum strength.

Asepsis and Antisepsis.

With all indirect measures in full swing there remained to be prosecuted the direct attack against infection of wounds. With asepsis a failure, surgical thought went back to Listerian days and keen search was instituted for antiseptics. Every day produced a new compound, mixture, or solution that enjoyed fleeting fame by its enthusiastic sponsor until supplanted by to-morrow's. Their legion merely attested, not their futility, but their universal shortcomings. Many of them were of considerable value, and some, like the "Bipp" preparation of the English, certainly at least in the hands of enthusiastic followers, gave happy results. But one and all had a common failing: in spite of proved bactericidal power ultimate healing of wounds was strung over a considerable period of time.

Gradually, however, from out the chaos there arose accepted principles that grouped themselves about one fundamental idea, the closure of wounds. So much of asepsis survives. The axiom that a wound closed by suture or other means healed more promptly and with less danger of infection was not disputed; the problem was to close these war wounds with impunity.

Debridement.

Through painstaking bacteriological and pathological study of wounds it was learned that even in the face of the wretchedly vile and dirty conditions under which wounds were inflicted, the tissues were for the first eight or ten hours not infected but merely contaminated. Bacteria were present but had not established a favorable habitat for themselves. If, therefore, the wound could be treated within that period and if all the contamination could be removed, the wound could be closed and aseptic healing expected. Practice proved the theory correct. Casualties received within the first eight to ten hours had their wounds completely excised, in one mass if possible, under rigid aseptic technique,—the debridement of the French. The excision had to be bold, ruthless, extensive, limited only by organs not to be cut. Attrition, cellular compromise, and devitalized tissue extend always one and often even two centimeters outside the actual track of the wound. Much has to be sacrificed; large, but not essential vessels tied off; fascia excised; and muscles cut even trasversely.

Ideal debridement is the removal of the intricate, ramifying walls of the wound in one mass in such a manner that the knife passes through only sound and uncontaminated tissue. It becomes imperative, therefore, to recognize tissue showing but the slightest and earliest evidence of impending destruction, a condition that has been aptly called local tissue stupor. Such tissue is damaged, not dead but prone to die, and almost certain to succumb to infection. It is characterized by dryness, lifelessness, anemia, and in the case of muscles by insensitiveness or sluggishness of response to stimuli. All such tissue must be excised. It is far better to cut away too much and be safe than to preserve doubtful tissue and watch apprehension turn to certainty of infection. Furthermore no sinuous tracks leading to potential cavities can be passed by; no shreds of hanging tissue nor loose fragments of bone can be left behind; and no bits of shell or clothing can be overlooked in the depths of the wound. Covering the entire interior of the wound with a solution of brilliant green which stains all tissues a uniform shade makes a helpful guide. Excision completed, clean gloves are donned and a new set of instruments used. Not a small factor determining success is absolute hemostasis; for a small blood clot may allow the propagation of a few bacteria inadvertently left behind that fresh normal tissue would destroy. At this point the repair of important structures that have been damaged must be accomplished. Severed tendons should be sutured by a nice ap-

proximation of the cut ends. Divided nerve trunks are to be carefully sought for and united. Immediate suture of blood vessels is rarely indicated because when main trunks are injured shock and hemorrhage intervene to prohibit any such extended surgical procedure. Even if sutured the attempt is very liable to be followed by aneurysm. As a matter of fact large arteries are rarely wounded. They are, however, often contused. When there is considerable contusion or doubt as to the permanent continuity of the vessel wall it is best to ligate in two places rather than incur the risk of subsequent aneurysm. Deep muscles are then loosely approximated with as few sutures of cat-gut as possible and the skin closed without drainage. Wounds thus treated within eight to ten hours of infliction will heal by first intention in about 90 per cent. of the cases in soft parts, and in about 50 per cent. in compound fractures.

The post-operative care is, however, of vital importance. Every wound must be splinted and so splinted as not only to insure absolute rest to the part involved, but also to preserve immobility until healing is obtained. In fact rest is so essential a factor that early evacuation to the rear or to home hospitals proved in itself a potent cause of failure to obtain first intention. It therefore becomes a rigid rule that if the case cannot be safely held at the place of operation for ten days, it is far safer not to attempt immediate suture of the wound but to be content with debridement only.

Delayed Suture.

A large percentage of the wounded, however, could not of necessity be treated within the eight to ten-hour period essential for primary suture. Also, many cases treated within that period had to be immediately evacuated because of the exigencies of the military situation. Corollaries of the eight to ten-hour dictum are that the chance of rendering a wound aseptic by debridement after an interval of twenty-four hours is small; after forty-eight hours, nil. Up to twenty-four hours, however, the chance is to be taken and is often surprisingly successful. These wounds are to be treated by thorough debridement and absolute hemostasis. Sutures for closing the wound are then placed but not tied and a large aseptic dressing applied. At the end of twenty-four hours and again at the end of forty-eight hours cultures of the wound are made, and if the first shows no streptococci and the second a level or falling bacterial count, the sutures can be safely tied with expected primary healing in about 60 per cent. of all cases. This is the so-called primary delayed suture of Duval. It is an equally useful procedure, in fact the one indicated, in those cases which, though otherwise favorable for primary suture, have to be evacuated prematurely.

So well established are the principles, so well defined are the indications, so precisely developed is the technique, and so brilliant are the results, that primary or delayed primary suture of every wound must be acknowledged the treat-

ment par excellence. No other method even approaches it in rapidity of healing, absence of infection, and freedom from deformity or impaired function. It is a step forward in aseptic technique unequalled since the birth of asepsis. To refuse it to a patient in civil life when under unfavorable war conditions it proved so successful must now be regarded just as surgically criminal as would be the employment to-day of the crude and obviously septic procedures of our fore-fathers. While it is highly probable that the future will bring forth a perhaps equally notable advance, it will do so, not by a miraculous jump from some rear position, but only through a cautious progress from this well supported forward station.

Carrel-Dakin Treatment.

When all is said and done, however, it is in the violently infected wounds which for the time being seemed hopeless that the greatest contribution to surgery is found. Dr. Carrel and Dr. Dakin, after patient intensive study, developed and perfected the technique that bears their joint names. To Dakin belongs the credit of discovering the most ideal antiseptic known: painless, actively germicidal, and harmless to normal tissue. To Carrel goes the credit of developing the technique that allows the antiseptic to produce its maximum effect.

Very briefly Dakin's antiseptic is a solution of sodium hypochlorite (NaOCL) of a strength between 0.45 per cent. and 0.5 per cent. and faintly

alkaline to alcoholic phenolphthalein but not to powdered. Unless made to conform exactly to these limitations it not only loses its virtues but becomes irritating, even harmful. The solution is very unstable, losing its strength rapidly in the light and slowly even under the best conditions in time. It must therefore be freshly made as needed and kept in closely stoppered, deeply colored, brown bottles protected from the light. The early and tedious methods of manufacture have been replaced by the quick and efficient method of passing chlorine gas in metered quantity through a measured solution of sodium carbonate for a calculated length of time. The necessary apparatus has been so perfected and simplified that the manufacture of perfect Dakin's solution is now within the reach of all[1]. It is absolutely essential that every liter made be titrated with decinormal sodium thiosulphate and tested with both powdered and alcoholic phenolphthalein in order to insure that the solution has the proper strength and alkalinity. Both tests must always be made, for the correctness of strength does not at all insure the correctness of alkalinity. Also any Dakin's solution kept for twenty-four hours or longer must be again tested before using. Its instability is annoying and precludes any short cut to success. A variation of even 0.05 per cent. in strength spells either dis-

[1]The apparatus designed and manufactured by Wallace and Tiernan Co., Inc., New York City is eminently satisfactory. Each outfit is accompanied by a small booklet giving full directions for setting up the apparatus, making Dakin's solution, and testing the product.

aster or ineffectiveness according as the variation is high or low.

The action of Dakin's solution depends primarily on the liberation of chlorine. Introduced into the tissues this liberation is completed in from ten to fifteen minutes. Its action would, therefore, be almost ineffectually fleeting were it not for the redeeming fact that by the action of Dakin's solution on tissue secretions chloramine bodies are formed whose antiseptic properties are considerable and whose action is prolonged. In addition to its antiseptic power Dakin's solution possesses to a high degree the ability to dissolve pus, slough, and necrotic tissue in a most surprising rapidity of manner. This in itself is a most valuable attribute. Most of the ordinary antiseptics are prevented from essential, intimate contact with bacteria by the protective masses of blood and leucocytes which surround them and on which most antiseptics have no destructive action. Dakin's solution is so prone also, not to dissolve blood clot, but by its solvent action on fibrin to dissolve the fine fibers that hold the clot in place and thus detach it in mass, that this contingency must be safeguarded by obtaining primary and complete hemostasis in all wounds to be Dakinized. Last, but not least, its prolonged action on normal skin is so irritating that the integument everywhere adjacent to the wound must be vigilantly protected by some sort of bland grease.

Because, therefore, of its quite unique properties Dakin's solution becomes effective only

when used in such manner as makes use of those properties. The technique evolved by Carrel is the only technique that correctly utilizes these properties in the way that brings about the desired end, sterilization of the wound. Four equally important and interdependent steps effect wound sterilization. The *first* may be named mechanical cleansing. This calls for expert and radical surgery, good surgery in every sense of the word, and most of all for sound judgment. Depending on the lapse of time since the injury was inflicted, wounds are found to fall into two main types: first a phlęgmonous type characterized by violent and unchecked infection with marked constitutional symptoms; and secondly, a frankly suppurating type, the sequel of the first, in which infection has become localized and general symptoms mild or absent. Between the two lie borderline cases demanding great nicety of judgment. In the phlegmonous type too much surgery is dangerous. All thought of complete excision of the wound must be sternly repressed in favor of superficial cleansing, removal of gross and easily found foreign bodies, and multiple incisions to secure free and ample drainage of every recess of the wound, measures just sufficient to render its whole aspect suitable for later management. More radical interference is certain to open up new channels for infection and invite its spread in spite of future treatment. In the frankly suppurative type, however, bold surgery is far less dangerous, in fact, generally indicated, though

often best postponed until some of the infection at least has been conquered. If operation is elected, the radical debridement already emphasized in the primary suture of wounds is to be practiced, but with great discretion. Nature's own defensive wall must not be breeched but jealously conserved. Obviously dead tissue, hanging shreds, loose fragments of bone, all bits of clothing and shell as predetermined by X-ray examination must be removed, and in addition pockets, sinuses, and branching cavities must be freely laid open even at some risk of extending infection; for the success of the next step leans heavily on the creation at this time of a wide open wound, of even contour, roughly cup or saucer shaped, with its greatest dimension at its exit in the skin.

The *second* step is the chemical cleansing of the prepared wound. This is the unique step in the Carrel-Dakin technique, though by no means the most important. So interdependent are the four necessary steps that the second, however nicely, persistently, and devotedly it may be pursued, fails always when its predecessor has been improperly executed. The agent employed for chemical cleansing is of course Dakin's solution. Other agents used in exactly the same way as controls have universally failed to sterilize wounds with the rapidity, thoroughness, and positiveness that Dakin's solution effects. Nor will Dakin's solution applied to the wound by any method except Carrel's accomplish at all brilliant results. The antiseptic must flood

the wound completely. Ubiquitous dispersion of the agent is assured by instilling it into the wounds through rubber tubes left open at the ends or with the ends closed and perforated at the sides. So exact and scientific is every point in the technique that the slightest deviation from the blazed path invites failure. The calibre of the tubing; its firmness and thickness of wall; the number and size of the lateral perforations, have all been worked out according to physical laws that must be obeyed[2]. Enough Carrel tubes are laid in the depths of the wound and along its sides to insure the delivery of solution to every area, held in position by lightly packed sterile gauze, and brought out of the wound at its highest anterior angle. The tubes must be long enough to project well beyond the bountiful dressing of gauze that covers the wound as well as the retaining bandage or swathe. The Carrel tubes are then joined through branching tubes of glass to one large rubber tube with a clamp that leads to a dark brown glass reservoir suspended above the patient. The reservoir holds the Dakin's solution, which by releasing the clamp is allowed to flow by gravity through the tubes into the wound whence it seeps out

[2]Instillation tubes are of rubber with an inner diameter of 4 mm., and a thickness of wall of 1 mm. Single opening tubes are 30 cm. long, ends left open, but a small side opening made near the wound end to act as a safety valve in case the end opening becomes plugged. Side perforated tubes are of four sizes, 5, 10, 15, and 20, respectively. The first two are 30 cm. long, the remaining, 40 cm. The ends are tied off with linen thread. Beginning at the closed end the sides are perforated

into the dressing. Instead of connecting the tubes to a reservoir each Carrel tube may be left lying independently outside the dressing and Dakin's solution instilled separately into each from a glass syringe. At first the wounds were subjected to continuous instillation by so loosening the clamp that a definite amount of solution was allowed to flow drop by drop in a given time. This was found to be exceedingly difficult to keep regulated and had the disfavor of keeping the patient constantly wet. Experience proved that after an instillation of a definite amount it took at least two hours for bacteria to recover from the shock of the antiseptic, so that continuous instillation has given way to intermittent, once every two hours day and night. It might appear on first thought that nocturnal instillations every two hours would so seriously interrupt the patient's rest that their general condition would suffer. This is really far from being the case. After the first night or two patients seldom are awakened by the instillations; in fact it is not at all unusual for them to doubt the most conscientious attendant's word that the instillations were faithfully given while they themselves slept. The amount to be used at each

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every cm. for the number of cm. indicated by the number of the tube. The perforations are 0.5 mm. in diameter and are made with a special punch. Covered tubes are simply side perforated tubes covered with Turkish toweling which covers the tube 5 cm. beyond the last side opening. Special tubes are No. 3, perforated every half cm. for 3 cm.; loop tubes, 70 cm. long, perforated in the mid portion; and empyema tubes, 50 cm. long, perforated every cm. for 10 cm., and stiffened with No. 22 gauge silver wire.

instillation cannot be expressed in definite measure, for conditions vary. A large wound requires more than a small one; the more tubes in a wound the more fluid is necessary, etc. The purpose is just to fill the wound; too much is mere waste and wets the patient; too little leaves some part of the wound untouched which can be easily recognized and corrected at subsequent dressings.

Because of its irritating propensity to normal skin, the integument everywhere adjacent to the wound which is liable to be bathed by the solution must be protected. The best protection is gauze impregnated with vaseline mixture[3]. Just before the dressing is applied layers of this vaseline gauze are laid on the skin about the wound and ironed out smoothly. Occasionally this fails to protect and a firmer substance must be used such as zinc oxide ointment generously smeared around the wound. Rarely there is encountered in the blue-eyed, freckled type of individual a skin that nothing will protect and the only recourse is to use Dakin's on alternate days or not at all.

Aside from the regular day and night instillations every two hours these wounds need attention only once a day when they should be completely redressed. To insure rapid sterilization

[3]A perfectly tight tin box is filled with pieces of gauze 9 by 17 cm. The box and its contents are sterilized by steam. While still hot the box and gauze are filled with a melted solution: vaseline 92%, hard paraffine 6%, resin 2%. When cooled it is easy to pick up as needed single thicknesses of gauze which are found to be thoroughly impregnated with the vaseline mixture.

the dressings must be done under rigid asepsis. With a little practice the entire procedure can be carried out easily with instrumental technique; the bare hands touch nothing and need not, therefore, be rendered surgically clean. An assistant, or even the patient himself, removes the entire dressing tubes and all. It is surprising to find how painless are all manipulations about Dakinized wounds. There is no sticking of gauze to be forcibly and painfully freed carrying with it strips of budding epithelium and leaving behind a raw, bleeding, tender surface. If the technique is being properly carried out the gauze slips away leaving bright pink, healthy granulations covered with viscid, shiny fluid, colorless, odorless, and at times stringy. Isolated collections of pus or areas of slough denote regions that Dakin's solution failed to reach, indicating that the positions of the tubes must be altered or more tubes inserted to correct the defect. The wide open wound is first irrigated thoroughly but gently with Dakin's and the excess allowed to run off. The granulations and especially the surrounding skin are gently scrubbed with a solution of neutral soap or gasoline until every caked bit of blood or flake of crusted serum is removed. It is beneath such detritus that bacteria flourish and prevent sterilization. The wound is then again gently washed with Dakin's solution and redressed exactly as at the initial dressing when it is ready for another twenty-four hours. With a little experience and competent team-work these

dressings can be done with great rapidity and pleasure to patient and surgeon alike. The absence of pus and lack of odor from these wounds are as remarkable as the painlessness is surprising; and the healthy appearance of wounds and patients is surpassed only by the rapidity of healing. Hard, bright red granulations grow with astounding speed quickly filling the wound. Very early the epithelial edge begins to proliferate. The thin blue line of new cells widens very slowly at first, but once the wound is leveled with granulations the rate of growth is greatly accelerated. This rate of cicatrization has been closely studied under all forms of treatment and no other method approaches the Carrel-Dakin in rapidity. A French physicist by means of a most ingenious planimeter is able to measure in square centimeters the exact area of any wound however irregular in outline. If the daily diminishing areas of a healing wound be recorded on a suitable chart a curve is plotted which approaches zero. By prolonging this curve he could predict the day on which cicatrization would be completed with most uncanny accuracy. Interruption of treatment or secondary infection, of course, disturbs the curve but curiously, if promptly corrected, does not affect the prediction; because renewed cicatrization after such interruption is strangely accelerated.

The *third* step is the bacterial count. As soon as the wound looks clean smears are made daily with a standard platinum loop full from the least healthy appearing portions of the wound

and the number of bacteria per field of the microscope carefully counted. In obtaining the smear blood must be carefully avoided for the erythrocytes rapidly clump and hide bacteria. If fifty or more bacteria are counted in the first field observed further examination is not made and the bacterial count is chartered as infinity. As the count decreases at least ten fields, better fifty, are counted and the average computed. Almost without exception the count rapidly diminishes to one or two per field, and thereafter more slowly. When the count shows one bacterium in five fields on two successive days the wound may be safely regarded as surgically clean, except in the case of compound fractures where the count of one in five fields must be obtained for five successive days. It has been vigorously contended, and still is, that the attainment of this minimum count does not certify to the surgical cleanliness of the wound unless it is also proved by cultural methods that none of those rare bacteria are streptococci. As a matter of fact it has been so conclusively proved by cultural methods that wounds having only one bacterium in five microscopic fields never harbor streptococci, that the bacterial count alone is sufficient to prove their absence; and the court of last resort, clinical experience, has ably demonstrated that wounds deemed sterile by bacterial count as often prove to be so as those so determined by cultural methods. Morever, cultural methods contain a deceptive source of unavoidable error. The bacteria held in the loop

for culture may be either accidental and transitory contaminators, or may be permanent inhabitants unacclimated and unable to grow in the presence of the defensive juices of the wound, but when transfered to the more suitable environment of artificial culture media regain their vitality. In either event the conclusions to be drawn from a positive culture are erroneous as regards the real condition of the wound. For all practical purposes, therefore, the much more simple and rapid determination of wound sterility by bacterial count alone is a perfectly safe criterion. If the bacterial count be regularly recorded on a suitable chart a curve is drawn which ever approaches zero. The first count is invariably infinity; but after an initial rise about the second or third day the count steadily declines with such rapidity that ordinary wounds of soft parts are surgically sterile in from five to eight days. More extensive wounds require a longer time; severely traumatized wounds, two weeks; and compound fractures freed from sequestra about four weeks. Let the treatment be interrupted and the count instantly rises. A soldier patient, a mathematician, while undergoing Carrel-Dakin treatment ingeniously worked out a formula by which from the chart he could calculate the day on which the wound would be sterile. While perhaps this formula may be of only academic interest, like the planimeter measure of cicatrization, the fact remains that in many instances the calculated date of sterility exactly coincided with the actual date, and

thereby, like the planimeter, gave proof of the scientific precision of the Carrel-Dakin technique.

The *fourth* and last step is the closure of the sterilized wound, the final goal, the consummation of the technique, and the measure of its worth. Because of the delay involved this late closure is designated secondary suture. The time when closure may be safely attempted is when the wound is pronounced surgically clean. Earlier attempt spells disaster, further delay merely postpones ultimate healing. Generally speaking the wound is healed eight days after secondary suture. In all small wounds, and in certain moderately large ones to be determined only by experience, it is obviously debatable whether time will be saved by secondary suture. These wounds are likely to heal by themselves in the eight days required for closure by suture. Whenever, therefore, the time necessary for spontaneous healing and for healing by secondary suture nearly coincide, it is wise not to subject the patient to the risk of further operative measures, but to allow the wound to heal naturally. The technique of secondary suture is very simple. Under general anæsthesia and strict asepsis the new epithelial margin of skin and the adjacent granulations are excised as a long strip and the fresh wound edges brought together with interrupted sutures. Undue tension on the stitches must be avoided. If the wound fails to coapt easily, undermining or other plastic procedure must be invoked. A large asep-

tic covering and a comfortable splint complete the dressing which need not be disturbed for a week. There will then be found just the fine linear scar that invariably follows suture of an incised wound. It is, for that matter, a happy sequela of all Dakinized wounds that, however healed, the resultant scar, irrespective of the size of the original wound, is never dense and thick but always thin and pliable. And in whatever manner ultimate healing is obtained, whether by primary suture, delayed primary, or secondary closure, the resultant scar must be treated with the greatest respect. Dire experience has taught that deeply imbedded in the scar isolated bacteria survive latently for weeks and months, harmless if left alone. But let the cicatrix be subjected to undue manipulation or insulted by premature operation the sleeping germs awaken into violent activity that not only undoes much of the local repair but even theatens life itself.

There can be no question about the matter: to Carrel and Dakin belong the credit for the greatest surgical discovery the war has produced. The idea, the possibility of sterilizing infected wounds by chemical means, is of course the original Listerian one and cannot, therefore, be truthfully called new, but the idea had been practically abandoned for years in favor of asepsis, so that Carrel and Dakin must be credited with at least resurrecting the principle and reapplying it. In so far as the means, and especially the agent, employed are concerned their work is indisputably new, and whatever changes

may be made in the technique through future experience, to them will the world be forever indebted for their conquest of infection. That the Carrel-Dakin technique actually accomplishes wound sterilization has been conclusively proved over and over again until it has earned its place in surgery for all time.

Because of such inherent disadvantages of Dakin's solution as instability, arduousness of manufacture, and difficulty of use, Dakin was spurred to further effort and later brought out two more antiseptics which he named chloramin T and dichloramin T. While more stable than sodium hypochlorite they are nevertheless decomposed by light and time and have therefore to be protected. Like the original Dakin's solution these are both chlorine compounds which accomplish maximum destruction of bacteria with minimum detriment to tissue; unlike the original their application is simple, does not demand special apparatus, and their manufacture is easy. While both can be used without irritation in much greater strength and perhaps, therefore, possess greater antiseptic power, neither possesses the inestimable property of dissolving pus, blood, and necrotic tissue. Chloramin T is soluble in water, more stable and prolonged in action than Dakin's solution, and can be used in strengths up to 2%. Non-toxic and non-irritating it may be applied in solution or as impregnated gauze, and is well suited for use in wounds already cleaned with Dakin's and free from slough. Mechanically

combined with sodium stearate it forms a whipped cream like substance or paste, Daufresne's paste, which can be freely spread over wounds. In this form its action is said to be prolonged, but its worth is not yet satisfactorily proven.

Dichloramin T is completely soluble only in oily media, best in the specially prepared solvent, chlorcosane. It contains twice as much chlorine as chloramin T and has a much stronger germicidal action. It can be safely used up to a strength of 20%, but for general surgical work a 5% or 8% solution is sufficient. As a rule oily solutions are hindered by the oil from obtaining intimate contact with infected matter and hence possess little antiseptic power. Dichloramin T, however, yields moderate amounts of antiseptic to watery media such as wound secretions and so exerts efficient germicidal action. The oil acts so to speak as a reservoir of available antiseptic which can be constantly drawn upon by the wound secretions. As the store is not exhausted for from eighteen to twenty-four hours the wounds need to be dressed but once a day. It is especially indicated in wounds that do not require irrigation or that have been freed of all necrotic material by Dakin's solution. The oil may be sprayed from an atomizer or be injected from a glass syringe. Contaminated wounds have been treated from the start with dichloramin T with most gratifying success. After careful debridement and absolute hemostasis the fresh

surface is well covered with the oil and the wound immediately sutured without drainage. Older infected wounds, prepared as for Dakin's solution, have also been perfectly sterilized by means of dichloramin T. The wound surfaces are first covered with coarse mesh gauze which has been thoroughly impregnated with paraffine. Then a generous amount of oil is poured into the wound which is kept open by a light packing of gauze. Since there is no excess solution used and no regular addition of fresh solution is instilled as has to be the case in the Carrel-Dakin technique, the amount of dressing material may be greatly diminished, a by no means negligible economy. No further attention is necessary or indicated for twenty-four hours when under rigid, aseptic, instrumental technique all gauze is removed, the skin around the wound cleaned with soap and water followed by benzene, and a new dressing applied. There is no grievous sticking of gauze which slips away painlessly without leaving a raw bleeding surface. Because of its ease of manufacture and application dichloramin T is an especially appealing antiseptic; but while its germicidal power and general efficacy are great it is not in the long run as rapid in action or as effective as the original sodium hypochlorite which with its additional unique solvent action on pus and necrotic tissue still retains its place as the most perfect antiseptic yet known.

Tetanus.

While the almost universal infection of

wounds with ordinary pyogenic organisms caused anxiety enough, two specific infections came to be regarded with special dread, tetanus and gas gangrene. These virulent anaerobic bacteria grew luxuriantly in the highly fertilized soil of France whence they obtained ready access to wounds. Prewar knowledge of tetanus was already considerable and experience gained in the war did little to shake that knowledge or add to it. The tried and proven prophylactic serum fully equalled expectations in as much as its compulsory injection into every wounded man almost completely stamped out the disease; but incidentally something new was learned regarding its nature, action, and dosage. That the severity of tetanic infection was, as heretofore believed, proportionate to shortness of the incubation period did not always hold true; in fact was not infrequently to the contrary. Some of the worst cases encountered developed only after a lapse of many days. A first prophylactic dose of 500 units proved sufficient for ordinary wounds; large or very dirty wounds require from 1000 to 1500 units. A primary dose of 500 units was so rarely followed by anaphylactic shock incident to subsequent injections that all danger on that score was eliminated. Traces of the first prophylactic dose are retained in the body for twenty-one days at the most but in quantity to insure immunity for only about ten days; a second dose is retained only seven or eight days; and a third even less with a proportionately shorter

duration of immunity. In other words repeated doses reduce the patient's ability to hold antitoxin. While it was found that tetanic patients have in their blood positive amounts of natural antitoxin, the amount is too small to render lasting immunity. Postponed surgery on tetanus wounds that have been healed for many months is, therefore, by no means devoid of danger; for not only does the bacillus of tetanus linger latent in the scar for long periods ready to activate when disturbed, but whatever natural immunity has been acquired is impotent, and a prophylactic dose given just previous to operation is of fleeting efficacy. Of all the possible routes for the injection of antitetanic serum the intrathecal is the most effective and most rapidly saturates the body, but the subcutaneous or intramuscular route is preferable for prophylaxis because being more slowly absorbed its action is more prolonged.

From the fore-going facts a prescribed prophylactic course of treatment was instituted that proved so effective that it can be positively relied on to prevent tetanus. Expect tetanus in all wounds was the premise. At the earliest possible moment every wounded man received 500 units subcutaneously or intramuscularly, and every seven days thereafter a similar dose until four had been given. If at a later period an operation became imperative another dose of 500 units was administered forty-eight hours before operation.

As it is impossible to tell from inspection of

the wound whether tetanic infection is present or not, early signs and symptoms of the disease must be promptly recognized. The classic signs of tetanus refer to a phase of the disease in which treatment has lost much of its power and value. Local rigidity, spasticity, or jerking of muscles adjacent to the wound, especially at night, are premonitory signs that precede the classic symptoms by hours, days, and occasionally even weeks. As the toxin of tetanus may become generally distributed by the blood stream as well as by continuity of nerve tissue, similar local manifestations may appear at any time in muscles far distant from the wound. All evidence of the disease may be entirely confined to just such localized manifestations which after persisting for months gradually disappear; but only too often the local signs are followed after varying intervals by all the distressing evidences of generalized tetanus. In the light of present knowledge, therefore, there is no excuse in the presence of such local signs for delaying either the diagnosis of tetanus or the prompt institution of vigorous treatment. Time is the most effective factor in success. In the way of treatment the wound of course should be laid wide open. Carrel-Dakin treatment probably offers the best method of local attack, but the value of any local measure is slight. As a matter of fact the war has done little except to emphasize the futility of all nonspecific remedies and the necessity of speedy

massive doses of the specific antitoxin repeated without stint as long as symptoms persist.

Gas Gangrene.

In respect to the other specific infection, gas gangrene, the story is profoundly different. Not only was prewar knowledge of the disease comparatively meager, but its incidence and morbidity were woefully unsuspected. Its prompt appearance on the battle fields of France, however, stimulated investigations that even if they have not beyond dispute produced a specific prophylactic and curative agent, have added greatly to knowledge of the disease and given promise of the early discovery of a potent remedy. In the process not a few preconceived notions have been refuted. The cause of the disease, for example, has been found to be due not solely to the *bacillus Welchii,* but to a variety of other anaerobic, gas producing organisms; *bacillus sporogenes, vibrion septique, bacillus edematiens,* and less frequently *bacillus histolyticus and bacillus Hibler.* Rarely from one wound were pure cultures of any one organism obtained; very often two or more types were found living symbiotically with aerobes which augmented their effect. The *bacillus Welchii* was, however, isolated from about 75% of all cases. The *bacillus sporogenes* alone is non-toxic but shows a determined tendency to grow symbiotically with any of the others whose activity it then enhances. The causative agent necessarily enters the wound as spores which mature only under anaerobic conditions.

It was not at all surprising, therefore, to find that about 70% of all wounds were contaminated with anaerobic bacteria which, however, because of unsuitable environment were far less often able to infect. Fresh, normal blood contains sufficient oxygen to inhibit the growth of these anaerobes. Therefore tourniquets, exsanguinated tissue, devitalized and necrotic structures are all so conducive to anaerobic growth that they must be avoided or removed. Muscle tissue proves to be absolutely essential for the production of gas infection; for no wound without muscle involvement was ever so infected. Once firmly implanted the bacteria grow with tremendous rapidity and manufacture an exotoxin that has two special predilections: one for muscle structure which it rapidly destroys with the production of an equally poisonous tissue toxin; and the other for blood which it as rapidly hemolyzes. This bacterial toxin has been isolated and from it has been made in a manner similar to the manufacture of diphtheria antitoxin a specific serum for which great hopes are entertained. The production of gas is rapid and voluminous. It has been conclusively proved, however, that the gas itself is not toxic but that by its pressure it acts in a very destructive mechanical fashion. An invariable accompaniment of gas infection is the more or less rapid development of varying degrees of acidosis.

Pathologically the process extends rapidly along muscle bundles always in a longitudinal

direction except occasionally when it invades the muscle coat of arteries when it may follow the transverse course of the vessel across the muscle. For that reason it not infrequently happens that only one muscle of a group or even occasionally but part of one muscle is involved. The rapid production of gas exerts a pressure that first effectually strangulates muscle bundles and deprives them of blood oxygen and then later bursts the enclosing sarcolemma allowing herniae of muscle fibers. The gas detected in the subcutaneous tissue is not formed there but has escaped from ruptured muscles. Strangulated tissue rapidly becomes gangrenous. The whole process extends with the most startling haste. Gas has been detected in a wound within the first five hours, followed by complete gangrene of the limb and death of the patient within fifteen hours.

It is quite common to find the disease divided clinically into different types. One frequently used classification is gas infection or gas cellulitis,—a local somewhat benign manifestation,—and gas gangrene which embraces the severe, explosive, fatal types with marked constiutional symptoms. Attempted classifications on an etiological basis are especially to be condemned, not only because the infection is invariably mixed, but also because in the present state of knowledge the part played by each kind of organism is not by any means certain. In this respect, however, it is recognized that the *bacillus edematiens,* when once firmly im-

planted, rapidly kills off other varieties and becomes the dominating organism. Such cases are as a rule quickly fatal. Another and finer classification subdivides into malignant gaseous edema, classic gaseous gangrene, toxic gaseous gangrene, and mixed. All such attempts at nomenclature are not only hair splitting and confusing, but unnecessarily futile. It is perfectly obvious that these are not different types of the disease but merely different stages in its development to be recognized as such. There are mild, severe, and perhaps even abortive cases just as there are of other diseases, depending on such many and complex factors as the virulence of infection, natural resistance of the patient, promptness and efficacy of treatment, etc. This conception of the disease is all the more to be accepted because of the perfectly obvious and natural division of the process into four distinct stages defined and limited by bacteriological and pathological findings. These stages may follow each other with startling haste at irregular intervals, or slowly and orderly without in the least altering the fundamental conception. The first is named the dormant stage. The wound is contaminated with the organism which has, however, not gained a sufficient foot-hold to produce in the wound the classical diagnostic appearance. Nevertheless, this is the period in which it is imperative to make a diagnosis; for when the old classical signs appear infection is so rife and so firmly seated that effective treatment is

difficult. On close observation it will be noted that the tissues in the dormant stage have a pale, dried-out appearance and are unusually insensitive and bloodless. The muscles have a dull, brick red color, do not twitch when pinched, do not bleed on section, on percussion yield a faint tympanitic note, and lack normal striations. The last named sign comes close to being diagnostic, for muscle, gangrenous from any other cause, fails to show loss of striation. X ray of suspicious muscle is also characteristic and is seen in no other process. The plates show irregular light zones around muscle bundles, changing as the infection progresses to light spots growing ever larger.

The second stage, gaseous distention, may appear within a very few hours or develop more slowly. It is characterized by the old classic signs: hard edema, bronzed skin, sharply demarked swelling, brownish serous discharge, an odor of putrefaction, slight often imperceptible emphysema, and such constitutional symptoms as dyspnoea, subnormal temperature, pallor, and rapid pulse. It represents strangulation of tissue, pressure from gas formation, and beginning gangrene. Accompanying the local manifestations is a rapid hemolysis that may go as low even as a million and a half reds. The hard edema and bronzing of the skin are undoubtedly the result of this marked hemolysis.

The third stage is the explosive. There is rapid progression of the local destructive process plus overwhelming invasion of dead

muscle with the causative organism. This invasion is accelerated by the gas itself. Myriads of bacteria adhere to the minute bubbles which are forced by pressure along the intermuscular septa. Muscle bundles rupture in quick succession filling the wound secretion with fine bubbles and distending the subcutaneous tissue until it crepitates like lung structure. In and about the wound occurs a gelatinous infiltration—edema plus hemolysis. This gelatinous infiltration forms readily between muscle layers and spaces where its excellent anaerobic position makes it an admirable culture media. Blebs filled with a thin most offensive fluid burst forth in profusion on the bronzed, shiny, distended skin. The stinking odor of gangrene is everywhere apparent. Signs of systemic involvement make their appearance as a beginning acidosis.

The fourth and last stage is that of systemic toxaemia. It follows its immediate predecessor with scarcely a pause and is itself of fleeting duration. To the above sufficiently distressing picture is added delerium alternating with profound stupor, rapidly failing pulse, low blood pressure, high fever, dyspnoea, and all the signs of an impending fatal termination. The cause of death is not a blood invasion by the micro-organisms, not an acidosis which is secondary, but a profound intoxication with definite and very potent poisons, the exotoxins from the infecting organisms and the tissue toxins from the action of the bacteria on muscle fibers.

Treatment to be effective must be promptly instituted in the dormant phase. The shocking mortality obtained early in the war can be laid solely and surely to the inability to make an early diagnosis. Cases reaching the fourth stage are moribund; the third stage, almost hopeless; the second, exceedingly critical; the first, hopeful. Occasionally because of high virulence of the infecting organism, lowered resistance, and other equally deleterious factors, early diagnosis and efficient treatment are unavailing and the patient dies. Not only must treatment be prompt, it must be energetic. Conservative surgery has no place in this class of infection. Under general anesthesia the wound must be widely opened up, all contused tissue removed, and especially every last bit of muscle that fails to twitch or bleed when cut must be ruthlessly excised. To be able to detect minute hemorrhage from muscle, tourniquets during operation are absolutely prohibited. In dealing with muscles it must be constantly borne in mind that the infection extends longitudinally and therefore every bundle that shows the slightest evidence of involvement must be courageously followed a little beyond the gross limit of disease. Needless to say every vestige of foreign material as denoted by X-ray must be removed. The same is true regarding hematomata. Clotted blood is an ideal culture media. Lay open by longitudinal incisions all suspicious muscular and vascular sheaths for the purpose of exposing all areas

of gelatinous infiltration. Last but not least split skin and aponeuroses with parallel longitudinal incisions. Avoid all transverse incisions because of their interference with the circulation of distal parts. After complete hemostasis has been obtained the institution of Carrel-Dakin treatment affords the best means of arresting and overcoming the infection. Amputation is the measure of last resort. It should never be done in the dormant stage until efficient Carrel-Dakin treatment proves unavailing which is not often the case. Patients seen for the first time in the second and third stages very often demand immediate amputation in order to save life. It is not by any means always necessary to amputate high well above all possible limits of infection; at a point just above the area of skin discoloration has proved amply sufficient. All amputations should be done after the guillotine method, augmented by lateral incisions through skin, subcutaneous tissue, and fascia, extending well up the limb, followed by Carrel-Dakin treatment.

Sodium bicarbonate should be given early in large doses and continued for many days in order to ward off or mitigate inevitable acidosis. Antitoxin can be tried at any time. In the critical toxaemic cases it is always indicated in the hope that it will bring about sufficient improvement to justify a quick amputation. The antitoxin must be composed of anti-Welchii, anti-edematiens, and anti-vibrion septique; one alone is not effective. Each must be prepared and

kept separately, but can be mixed just before using.

Compound Fractures.

A large percentage of the battle wounds involved bones. Compound fractures, therefore, were extremely common. Not only did these lesions share the subsequent infection that complicated wounds of soft parts, but they also, because they offered the maximum possibilities, succumbed more easily and clung more tenaciously to infection. Once the problem of the management of compound fractures was reduced to terms of prevention of infection and vigorous antiseptic treatment great advances were made. All the heterogeneous varieties of splints for every conceivable fracture were scrapped in favor of a few simple efficient ones that were standardized.[4] Splints that depended for their immobilization on circular bandages that possibly, and often did, constrict circulation were discarded and preference was given to those that maintained equally good immobility through the principle of extension. The compulsory immediate use of the Thomas splint alone greatly reduced the mortality from compound fractures, lessened the ravages of infection, and preserved countless limbs that would otherwise have been sacrificed by imperative amputation. No small factor in the

[4]Standardized splints. Wire gauze 6x36 inches, Jones forearm "cock-up," Thomas traction arm, Jones humerus traction, Jones rectangular foot, Cabot posterior wire, Thomas traction leg, long Liston, Bradford frame, Balkan frame.

success claimed for the Thomas splint, however, was the strict observance of the dictum that the original splint remain undisturbed irrespective of frequent transfers of the patient, until union was firm. The application of the principles of wound closure and sterilization so further improved the results that Depage was able to show ward after ward filled with cases of compound fracture without a drop of pus.

A very short experience with debridement in compound fractures demonstrated that the bruising and laceration of soft parts extend far beyond limits hitherto suspected. Excision must, therefore, be even more extensive than in simple wounds. Loose bone fragments, often driven very far indeed, are to be carefully sought and removed but no fragment that is attached to viable periosteum or muscle should ever be sacrificed. A favorite site for small loose splinters is the exposed marrow. The medullary canals should anyway be thoroughly curetted for a depth of about three quarters of an inch, as it is into this soft cancellous bone that infectious matter is frequently driven. So essential is this curettement that it is to be done even at the expense of removing a healthy fragment that blocks approach to the marrow. Often, however, such viable fragments can be preserved by carefully cutting and lifting the binding periosteum along one side, using that on the other as a hinge that will preserve its nutrition. As for the internal fixation of bone ends, that is rarely indicated at the primary

operation and when done only the simplest and quickest methods are permissible. Plates of foreign material and autogenous bone grafts have proved useless, even harmful, at this stage of the treatment. On the other hand it is most important to mold all the comminuted fragments into a compact mass that fills the deficiency between the main fragments; it is even permissible, when necessary, to hold the mass in position by deftly placed sutures in surrounding muscles. Last and of the utmost importance is complete hemostasis, for nowhere as in bone does blood clot so encourage infection.

With the attainment of hemostasis the analogy between the treatments of simple wounds and compound fractures abruptly ends. Even in the eight to ten hour period primary closure of compound fractures proved most disappointing. It may be that the virulent bacteria of the war zone account for failures that would not obtain in civil life; it may be that the extensive comminution of bone incident to war wounds and less often encountered elsewhere is the explanation; it may be any one or any combination of many other possible factors that is at fault: but the fact remains that in the recent war primary suture of compound fractures so often and disastrously failed that the attempt was pretty generally abandoned. Further experience, however, demonstrated that the bone involved had an important bearing; for it was learned that compound fractures of the clavicle, ulna, and radius could be closed by primary

suture not only with an even chance of success but also without jeopardizing life or limb. Whether or not this limitation to primary closure is going to obtain in civil life can be answered only by further experience under circumstances less harrowing than those prevalent on the battle field.

Delayed primary suture proved equally disappointing. There was, then, nothing to do but to leave the wounds wide open and to pin entire faith on chemical sterilization, the original principle whose successful application had emboldened pioneers to develop and perfect the early closure of wounds. The faith was not misplaced. In no other class of cases have the results of Carrel-Dakin technique proved so brilliant. Fresh compound fractures, that is those received within twenty-four hours, can be completely sterilized in from three to four weeks when secondary closure will succeed in a good majority of the cases. This is indeed a marvelous achievement to be fully appreciated only when compared with the weeks and months of septic course that compound fractures often used to follow only to end in a chronic condition that sometimes never healed. It is freely admitted that the good surgery practiced is the indispensable fore-runner of the success of the sodium hypochlorite solution, but good surgery is also part and parcel of the Carrel-Dakin treatment constantly emphasized by its authors, so that no credit is to be withdrawn from its originators on that score. Furthermore, equally

good surgery followed by other technique has never in compound fractures also equalled the success obtained with Dakin's solution. Continuous immobilization and extension is of course absolutely essential. The standardized splints easily lend themselves to the requirements of Carrel-Dakin technique, nor do they in the least hinder or obstruct subsequent dressings. Extension by means of adhesive plaster has been superseded by equally efficient glues, such as Sinclair's.[5] This glue melts at a temperature that does not burn skin, is easy and cheap to make, does not require shaving of the part, and of the greatest importance does not macerate the integument. It is applied hot with a paint brush stroked against the growth of hair. A strip of folded gauze or muslin is laid on the soft glue and smeared to the skin with a few strokes of the brush. The glue hardens smooth in about twenty minutes when it is capable of withstanding considerable steady pull.

Osteomyelitis.

In spite of painstaking treatment some fresh compound fractures yielded to infection that, successfully driven from soft parts, became firmly seated in the more vulnerable bone. Almost without exception cases neglected from

[5]Sinclair's Glue.

Ordinary white glue	50	parts.
Water	50	"
Glycerin	2	"
Calcium chloride	2	"
Thymol	1	"

any cause developed bone infection of varying severity. The result was a vast collection of cases of chronic osteomyelitis whose prolonged course crowded the hospitals with a most discouraging amount of sepsis. Cases were operated time and time again only to be followed by the formation of persistently discharging sinuses. Much of the surgery failed because it was ill-timed. Experience established two dangerous periods in the course of compound fractures when operative interference is not only futile but harmful: first during the phase of acute phlegmon; and second at the time of union. Cases of non-union should be left alone eight to ten weeks. Even with the avoidance of these two fateful periods, however, surgery was discouraging until the Carrel-Dakin technique was perfected. The results then obtained far surpassed in brilliancy anything yet accomplished by that means, because it offered a certainty of cure for a condition otherwise chronically hopeless. While much of the credit reverts again to the solution of sodium hypochlorite, the recognition and application of a surgical principle is equally meritorious. Cavities heal by the collapse and consequent opposition of their walls. Cavities in bone, which are the essential cause of the perpetuation of osteomyelitis, cannot heal because their walls are rigid and cannot collapse. Therefore, the cavities must be obliterated. When this is accomplished by the bold removal of irregularities of the walls, and over-hanging bone, healing

occurs. A bottle shaped cavity in bone never heals. No adequate treatment of bone cavity analogous to the dentist's management of a tooth cavity has yet been devolved. The only successful procedure so far found is the conversion of the deep, narrow, irregular cavity into a wide, shallow, smooth, saucer-shaped area to be subsequently bathed with Dakin's solution. Tunnel cavities through bone will not close until either the roof, floor, or one side of the tunnel is excised. Seemingly excessive amounts of inherently healthy bone have to be sacrificed, but there is no other way. Not a small factor in the success of this extensive osseous debridement is the removal of occult bone areas potentially liable to necrosis and sequestration. It is surprising how quickly these large cavities fill. Granulations grow rapidly from adjacent muscle and other soft tissue; skin quickly epidermizes over them; osteoblasts invade them and form new bone; and in time the primary depression in the contour of the bone becomes leveled. Perfect immobilization of the wound must be constantly maintained until healing is fully completed.

Face and Jaw Wounds.

Of not unusual occurrence were most distressing wounds of the facial and jaw bones that attracted particular attention, not only on account of the sometimes hideous disfigurement they caused, but also on account of the difficulty of dealing with them. The difficulty was the

natural outcome of an attitude that contemplated dentistry and surgery as two distinct and separate professions. This feeling the war abolished. It is now an axiom that wounds involving the jaws and adjacent soft parts are to be treated concurrently and coöperatively by dentist and surgeon, not as formerly independently and in sequence.

The blood supply of the face is so good that the eight to ten hour limit for primary closure can be safely extended to twenty-four hours. While infection in wounds of this region is common, perhaps constant, it is never alarming, and anaerobic infection is unknown. Temporary immobilization should be secured immediately and permanent splinting as soon as infection is localized or under control, and while the bone fragments are still mobile. Great ingenuity is required for each case is a separate problem. The constant aim should be to prevent disfigurement by preserving the normal contour of the face; and to provide good dental occlusion by proper alignment of fragments. Spontaneous union by filling in can be confidently expected when the loss of bone does not exceed half an inch; and is not impossible where the loss is as much as three-quarters of an inch. More than that requires bone grafting. The callus can, however, be considerably stretched during its formation, but must be done very gradually, so that it is, therefore, rarely necessary to sacrifice contour or occlusion for the sake of union.

Besides the control of hemorrhage and infection, which is perhaps the sole province of the surgeon, there is anatomic restoration, the particular job of the dentist. All three can and should be handled simultaneously. Dental prosthetic appliances are numerous and many of them predicate special training for their application. The temporary splints, however, are simple and their use easily mastered. If the upper jaw is intact a very efficient temporary splint is made by putting modelling composition between the teeth, pushing the lower jaw up into it in nice occlusion and holding it there by a chin cup. The composition rapidly hardens and preserves the reduction. At the best, however, it is but a crude makeshift to be used only in emergencies; for it allows neither adequate breathing space nor room for subsequent swelling of the parts. A far better device is the Gunning stock dental splint of aluminum. It consists of an upper and a lower cup, each filled with modelling composition and so hinged with its fellow as to simulate normal vertical jaw movements. The teeth are forced into the respective cups in a restored position, the jaws brought as near together as the splint permits, and a chin cup added. The Gunning splint has all the advantages of modelling composition alone, is standardized, cheap, and portable, and has the desirable additional feature of fixing the mouth open. Modifications of the above with outside attachments to fit individual cases, and intermaxillary fixation by direct wiring, belong

exclusively to the dentist. The same is true of the ingenious use of minute jack-screws which turn by turn gradually stretch the growing callus and further restore normal contour. On the other hand bone grafting falls properly to the surgeon. The best grafts are obtained from the nearer clavicle and are transferred by a two stage operation. The graft is cut and one end transferred to its new site leaving the other end as a pedicle attached by the sterno-mastoid muscle. At the end of ten days when the pedunculated graft has established circulation from its new insertion, the pedicle is cut and the graft swung into place. With its vitality in its new site assured the graft can be then so molded by the dentist with his interdental splints or direct wiring as to correct possible defects of contour or errors of occlusion.

Septic Joints.

Nowhere perhaps in the body has infection been harder to deal with than in joints. For years septic arthritis has freely travelled a most destructive course leaving in its wake completely disorganized joints, often with persistently discharging sinuses, inevitably with ankylosis, partial or complete. The classical operation of wide incision and free drainage did not in the least alter the course of things, except to save life. The certain end results were permanently impaired, often nearly useless, limbs which the unfortunate possessors of at last sacrificed most willingly. Early in the war,

therefore, wounded joints, because of their certainty of infection, presented such horrible problems that it is not perhaps surprising that premature amputation was often advised with the assurance that if accepted months of suffering and an eventually disabled limb would be avoided. Before the war a bold pioneer here and there had advocated as a substitute for incision and drainage thorough chemical cleansing of the opened joint which was to be closed immediately by suture. To the conservative surgeon the procedure savored of such extreme radicalism that it was frowned upon and generally ignored. Given free opportunity, however, with the many joint wounds incident to the war progressive surgeons succeeded in demonstrating that the idea of closing wounded joints was practical. From their bold enterprising work it has been proved that synovial membrane is itself markedly resistant to infection and fully able to take care of a not inconsiderable amount without damage to itself. It is the capsule of the joint and the extra-articular tissues that are vulnerable and to be feared. The fate of a wounded joint depends, therefore, upon the success with which wounds of the soft parts surrounding the articulation are treated.

Small perforating wounds without fracture generally heal promptly under simply compression and immobilization; more extensive wounds can be treated according to the rules already laid down. Within the eight to ten-

hour period careful debridement of periarticular tissues and synovia, removal of foreign bodies, and thorough irrigation of the joint with mild antiseptic solution, can be followed by primary suture. Thereafter extension, immobilization, and a stern attitude of non-interference will bring about first intention healing in about 90% of the cases. Beyond the eight to ten hour period, and even when obviously septic, joint wounds should be excised, irrigated, and the synovia closed immediately by suture but with drainage of extra-articular tissues down to the synovia. Under such treatment it is surprising how quickly and completely in many instances the signs of intra-articular infection subside and how good a functional joint results. Long standing septic joints are of course another matter. Here, not only has the synovia been destroyed, but the joint cartilages have been eroded and the peri-articular structures thickened and deformed. Incision and drainage result only in endless discharge and a useless limb. Resections have not effected quick subsidence of sepsis nor favored bony union. On the whole amputation, as soon as the case is deemed hopeless, gives the lowest mortality, the shortest convalescence, and the best satisfied patient. The method devised by Speed of subcrural drainage of the knee joint by a tube in the upper end of the pouch, the leg in extension in a Thomas splint and slung from a Balkan frame, turning the patient on his face for two hours twice a day, is worthy

of further trial, and may be found to be the means of saving otherwise hopeless legs.

With eventual ankylosis certain because of the severe nature of the injury, sepsis, or what not, it is imperative that ankylosis be obtained in the position of greatest usefulness. In the shoulder the humerus should be so placed that its axis makes an angle of seventy degrees with the vertebral border of the scapula. In the elbow a position of 110 degrees is the angle of choice. The knee should be very slightly flexed.

Amputations.

Due entirely to the marvelously improved methods of treating and controlling severe infections, the indications for amputation have themselves been amputated one by one. Limbs that heretofore were deemed hopeless can now be saved. More and more should this idea be encouraged and tentative attempts made to save every limb; for the Carrel-Dakin technique offers positive means of preserving tissues that were formerly lost. Next to severity of injury and virulence of gross infection, the tourniquet is directly responsible for most amputations. Eighty per cent. of wounds whose blood supply has been cut off by tourniquets for a period of three consecutive hours eventually come to amputation. If a tourniquet must be used, place it always just above the wound in order that as few distal segments of the limb as possible may be deprived of blood. Then in the event of later imperative amputation section may be made

just above the line of the tourniquet and several inches of limb that would otherwise have suffered from a higher placed tourniquet can be saved.

Stress is now laid not so much on the indications for amputation as on the kind of amputation indicated. The early struggles with grossly and virulently infected limbs, shattered beyond all hope, taught through the occurrence of continued sepsis in the stumps that the guillotine operation still really occupies a place in surgery. Though it results in a poor stump, almost impossible in the lower limbs, a poor stump on a live patient is far preferable to a good stump on a dead one. In other words the guillotine operation is solely a life saving measure. Even when healing is complete such stumps are impossible to fit satisfactorily with a prosthesis; and in the lower limbs where the stumps must bear weight the circular amputation seldom allows weight bearing because the scar crosses the end. Whenever, therefore, the guillotine operation is performed it must be with the expectation that later on recourse will be had to a secondary amputation. There is, however, this specific exception: if the secondary operation will convert a healed circular amputation in the middle third of the thigh into one in the upper third, it is preferable for prosthetic reasons not to re-amputate but to preserve the extra length of femur with an imperfect stump. All circular amputation stumps are to be left wide open and subsequently treated either ac-

cording to the rules of delayed primary suture or, after sterilization by Carrell-Dakin technique, on the principle of secondary closure.

The management of bone ends has undergone radical changes through a correct appreciation of the role played by the periosteum and exposed marrow. These structures have been proved to be the guilty cause of those painful stumps that are accompanied by an over-growth of bone. The old theory that these tissues must be preserved is, therefore, no longer tenable. Instead, the entire circle of periosteum must be thoroughly scraped away from the bone end for a space of one to two centimeters, and the marrow curetted an equal distance. Rarely indeed does the compact bone so exposed suffer from lack of nutrition as evidenced by the later formation of sequestra which demand removal. On the other hand, painful stumps from exuberant osseous growth are absolutely prevented.

In general it should be a fixed rule to save every inch of limb possible. This is always feasible in the upper extremities where the kind of operation indicated should be that which preserves the longest stump. So great have been the improvements in prosthetic appliances that the loss of an inch from the stump to be fitted may fatally preclude the enjoyment of an artificial arm whose dexterous mechanical features depend entirely on that sacrificed inch. Moreover, every bit of muscle and tendon that can be preserved around the stump is of inestimable value. Very ingenious plastic operations have

been devised which make use of these muscles and tendons to activate by voluntary contraction the inanimate fingers of a false hand.

In the lower limbs, on the contrary, the goal aimed at is a good weight bearing stump. To this end sacrifices in the length of bone and in the mass of muscles and tendons, blameworthy procedures in the upper extremities, are often justified in the lower limbs for the sake of better weight bearing attainment. End bearing stumps are to be preferred because they preserve some sense at least of ground feeling. Emergency guillotine operations should be, therefore, so planned that at the secondary amputations end bearing stumps can be constructed without undue sacrifice of tissue. The old points of election for amputation have to a large extent lost favor which now redounds to considerations of usefulness and weight bearing. The attention paid to anatomical limitations is no longer positive but negative; useful and weight bearing stumps are possible at nearly all levels except as a general rule through joints or close above them. In the foot, however, Syme's amputation has returned into vogue provided the articular surface of the tibia is preserved and the malleoli are shaved off laterally.

Surgical Shock.

In spite of the unparalleled opportunities for observation and study of surgical shock that the war so generously supplied, the cause of the affection remains in darkness. Old facts

regarding its phenomena have been amply confirmed and emphasized, and empirical methods of treatment to correct the symptom or syndrome that most appealed to individual investigators as the dominating feature, have been enthusiastically promulgated with varying degrees of success. Some of these are not even new but merely resurrected from a forgotten past. To reiterate, for example, that the fundamental trouble in shock is loss of blood plasma into the tissues is a wearisome, hackneyed statement that means nothing. Admirable as are the reports of special commissions in restating and correlating the facts, they offer nothing fundamentally new. Unfortunately lack of confirmation, not infrequently amounting to actual disagreement, but further befogs the main issue. On the whole, considering the mass of available material for study the total results are keenly disappointing.

However that may be, the knowledge gained is not entirely negligible. The enormous number of shock cases that occurred gave an unrivaled opportunity for investigation; and the frightful mortality from that cause alone added a stimulus to endeavor that was bound to be productive of something. The attack on the problem was made in what proved to be the ideal way. Special shock teams were organized and equipped to deal specifically with shock cases. Near the operating theatres rooms were set aside for the exclusive use or these teams, whose almost instant results fully justified their con-

ception. It was not that new specific remedies were suddenly and miraculously discovered, but simply that by intensive study and observation old facts regarding shock were correctly correlated and well-founded principles of treatment were deftly applied by new ingenious means which proved to be more potent.

Two distinct types of surgical shock are now well defined. The first is styled acute. It develops very quickly in men whose wounds are so trivial and whose exposure to the other usual causative agents is so fleeting and mild as to be negligible factors in its production, that it can be explained only by the highly organized nervous temperament which such cases universally exhibit. It has been not unfavorably compared to ordinary syncope. It is, however, a serious condition, often becoming critical, occassionally even fatal, without prompt and energetic attention which as in syncope is generally fruitful. The second type is the more familiar one of slower and more insidious development that aggravates severe bodily injury and is often fatally progressive in spite of every treatment. This is the kind of shock most frequently encountered, constituting the classical syndrome whose etiology is obscure and many of whose phenomena are imperfectly explained.

The influences of fatigue and cold on the production and aggravation of shock have long been recognized, but probably never so fully appreciated as now. So important have these causative or at least contributary, factors been

proved to be that it must be forcibly emphasized that it is impossible accurately to estimate the true condition of a shocked patient until he has been rested and warmed. Fatigue cannot like cold be measured clinically, but if it is at all commensurate with the degree of cold observed in shock it must often be extreme. Low temperatures, even below ninety-two degrees, the lowest mark on the common clinical thermometer, were not at all unusual; and following shocking injuries to the sixth, seventh, and eighth cervical segments of the cord readings as low as eighty degrees were found. Fatigue and refrigeration are factors whose influence is not only sufficient to mask the real state of the vasomotor system, but is also capable of so aggravating its failing powers from other causes as to bring about a fatal issue. Whether cold and fatigue are cause or effect is beside the question; they are universally present in shock and by their presence aggravate the shock. In this connection it must not be forgotten that the summation of painful and emotional stimuli produces a state of fatigue as surely as does muscular exertion, and more perniciously. It has to be granted, therefore, that shocked patients are cold and tired, and such being the case it behooves surgeons not to size up things too rashly. These factors, moreover, can deceive in both directions; they may temporarily be the dominating causes and as such make a case appear worse than it really is; or through delay in the full disclosure of their sinister potentialities they may

fail to refute a false sense of optimism wholly justified by the meagreness of other causative agents. The safe course lies somewhere between impatience and procrastination.

The most reliable measure of the degree of shock as well as the most accurate guide in prognosis is frequently repeated sphygmographic determinations, more specifically, diastolic readings. Blood pressure observations have absolute as well as relative values. A diastolic level of 60 mm. is the critical level; below 50 mm., fatal. A low diastolic pressure accompanying a systolic as high even as 100 mm. invariably affirms shock. If the diastolic reading fails to rise with appropriate treatment, irrespective of systolic behavior, the case is hopeless. The longer blood pressure remains low the more difficult becomes the matter of resuscitation; the more profound are the metabolic changes of reduction of alkali reserve and acidosis; the more unlikely is the eradication of the effect of these plus the original shock; and the more arduous is the restoration of equilibrium and control of the nervous system.

There is still no specific remedy to prevent or combat shock and there will not be until the fundamental cause of the condition is learned. The nearest approach to specific treatment, whether the shock is due to hemorrhage or not, is blood transfusion from suitable donors. Transfusion by any proved method after correct typing of donor and recipient is very rarely indeed accompanied by danger in the hands of

competent operators. Its efficacy is not only unquestioned, but its advantages are far superior to all other methods of restoring fluid to the vessels. Intravenous salt solution so quickly escapes back into the tissues that its action is very fleeting. Acacia, gelatine, and other colloid solutions compounded to correct this fault are not without danger and fail to remain in the vessels. The serious objection to transfusion that it is often difficult to obtain a suitable donor on the spur of the moment has been met by the discovery that blood corpuscles may be preserved in dextrose and stored on ice for as long as a month without losing their viability. Transfusion with stored blood has achieved results as good as those from fresh blood, and is without additional danger.

Many methods of treatment may perhaps be specific in the sense that they are such against one phenomenon alone. The fault with each of such remedies is that it postulates a single symptom as the primary and controlling factor whose successful elimination cures shock. These methods of treatment are based many times on purely theoretical premises, propped up by positive but incorrectly interpreted scientific facts, and exploited by empiricism. Often they prove curative only in the hands of their enthusiastic and perhaps biased sponsors. Sodium bicarbonate administration, for example, predicates an acidosis as the dominant feature which is by no means proved or generally accepted. Acidosis is best to be viewed not as always a causa-

tive factor nor as always the chief phenomenon, but is rather to be construed as only one of many frequent associated changes due to an unknown primary cause. It cannot be denied, however, that not infrequently bicarbonate of soda does cause improvement, but when it does so the case is best regarded as one in which for some reason acidosis plays a prominent part and other features are as strangely in abeyance. Its use would seem, therefore, to be restricted rationally to those cases of shock evidencing certain or impending acidosis, when its administration assuredly combats so much of the effects of shock as are due to the associated acidosis. The inhalation of carbon dioxide, either as pure gas or as rebreathing of the patient's own expirations, is an accredited remedy based on the well known property of that gas to stimulate deep inspirations. Shallow, rapid, ineffectual respiration is almost universal in shock. The diaphragm therefore fails to exert its full power of sucking blood into the right heart. The theory is that under carbon dioxide stimulation the excursion of the diaphragm is increased, a higher negative pressure is created in the thorax, and blood is thereby aspirated from the venous and capillary systems and returned to active circulation which corrects the fundamental fault. Whether or not it works out according to this theory, the fact remains that the method has produced some very startling results and deserves further trial.

When all is said and done, however, it is the

common sense measures based on well proven facts that are most reliable. Once the true portent of the deleterious factors of fatigue and cold was correctly appreciated measures that would ably combat their dire influences were sought and instituted. The causes of fatigue in its widest sense are manifold, and are both physical and emotional. A certain degree of bodily weariness and mental usury, the latter manifested by either depression or excitement, was a constant sequela of the perilous exigencies of trench life. In other words the soil was prepared for the quick production of fatigue. The effect of the actual physical destruction of tissue was rapidly augmented by the steady flow of pain sensations from the wound and the exhausting play of the suddenly created emotions of fear, grief, and the like. Hunger and thirst soon added their quota until a well marked degree of mental and physical exhaustion was present. The obvious antidote was prevention. The wound itself must be spared all unnecessary handling and put definitely at rest by proper splinting. Rough manipulation, even with the laudable purpose of restoring anatomical relations, is often sufficient to shove balancing patients over the threshold into severe shock. Transportation must be reduced to a minimum. Even a comparatively smooth railway journey has a bad effect. It was early noted, for example, that a man with a compound fracture of the femur who in warm, clear weather lived in the open for several days without treatment,

reached a hospital in better shape as regards shock than one who was picked up and moved without delay. Left alone the wounded man kept his leg at rest and thereby warded off or recovered from his shock. Such observations as these warrant close attention when other considerations compel his prompt removal from surroundings bristling with other causative agents. Transportation unavoidably provides painful stimuli whose summation produces fatigue or intensifies beyond his endurance fatigue already present. As some transport is inevitable the rest that cannot be assured by splints and posture must be invoked by the free use of sedatives. Morphine is the drug par excellence and should be given in half grain doses. At this point it must be sternly emphasized that much of the benefit from morphine is dissipated if the patient is at once started on his journey. The administration should be so planned that a period of at least fifteen minutes be provided for the injection to take effect; otherwise the premature induction of painful impulses breaks down the half made sedative barrier that even the full effect of morphine is unable later to close. As a substitute for morphine a British preparation, omnopon, is said to have about two thirds the sedative power of morphine and to be without the latter's depressing effect on metabolism and vital nerve centers. Duskiness of lips and finger nails indicates an impairment of oxygenation. It

may be due entirely to the deficient respiration accompanying shock, but not always. Cyanosis is an unmistakable fore-runner of acidosis, which must be construed as at least an associated change of dire potentiality. Morphine, by further depressing respiration, may further increase cyanosis and hasten acidosis. The opposing dangers, therefore, of pain and exhaustion, cyanosis and acidosis, must be nicely balanced in arriving at a decision to give or withhold morphine.

While prompt removal from places of danger where fear of being hit again, of capture, and of death excite a rapid play of exhausting emotions, it often becomes a matter of nice judgment to decide whether or not the necessary transportation may not be the greater evil. Morphine is indicated in either event, in order to blunt these emotions. It is agreeably surprising to note how often merely an hour's rest changes a patient's general condition from seeming hopelessness to ability to endure transportation, or even surgical intervention, with impunity.

Equally as important as rest is the preservation or restoration as the case may be of normal body temperature. Cold is not only a powerful factor in the production of shock but it always appears coincidently with the development of shock. Unless guarded against, the absolute rest demanded will in itself, by inhibiting such natural safe-guards as shivering and deep breathing, lower still

further the body temperature. It is imperative, therefore, that heat be applied. Many were the ingenious methods of so doing that were under the spur of necessity devised from inadequate materials. It makes little difference from what source external heat is obtained, but it must be constantly remembered that shocked cases are less sensitive to heat and demand, therefore, greater watchfulness against burns. Internally heat is supplied by the ingestion of hot fluids, nutritive if possible. In this connection it is well to bear in mind that shock cases are very frequently nauseated and that anything introduced into their stomachs may easily excite vomiting. Not only is coveted heat and nutrition thereby lost, but the exertion of vomiting further aggravates existing shock. On the whole the best drink is tea with milk and sugar, a combination that is palatable and much more often retained than any other. Measures to combat fatigue and cold must be carried out simultaneously and not in sequence, otherwise much of their potency is lost. Vigorously pursued many a seemingly hopeless case has been revived and permanently restored when all other measures against shock were unavailable. Until the primary cause of shock is learned and a rational specific remedy is devised, common sense measures offer the best and least indispensible methods of treatment.

Anesthesia.

For general anesthesia ether has again been proved to be the safest agent. The open method of its administration, however, was so chilling and irritating to bronchi already inflamed by the cold damp air of the trenches that post-operative pulmonary complications were frequent. The substitution of warmed ether vapor by closed methods promptly lessened the incidence of respiratory sequelae and came to be generally used. A mixture of ether and chloroform in the proportion of sixteen to one has proved a pleasing combination preserving the safety of ether, devoid of the inherent dangers of chloroform, but retaining its ease of induction. Stern necessity courted the invention of simple makeshifts which would do away with the expensive and complicated apparatus devised for special refinements in anesthesia, and at the same time preserve their essential features. A rubber tube, for example, slipped over the spout of an ordinary ether can and connected with a nasal, pharyngeal, or intratracheal catheter, was a most simple expedient that gave very satisfactory insufflation anesthesia. Air entered the can through perforations in the top, passed over the ether, and thence was aspirated by the patient's own inspiratory exertions. Gentle agitation of the can plus the warmth of the anesthetist's hand served ably to concentrate ether vapor to any degree required. Doubt-

less many other equally simple and ingenious make-shifts were devised by men whose innate modesty or unobtrusiveness has tabooed publication or exploitation.

Roentgenology.

Forward strides in the field of roentgenology have led in the last four years to miraculous developments. Without these remarkable advances the equally astounding achievements in surgery would have been greatly curtailed. The heretofore immobility of the X-ray plant which compelled Mahomet to come to the mountain has all been changed. There have been invented easily portable X-ray outfits, marvels of compactness, lightness, and ease of adjustment, whose products at least equal those coming from their immobile counterparts. This one feature of portability has put at the free disposal of surgeons wherever placed an indispensible adjunct to their art. No longer must patients forego the aid of roentgenology because their condition is so critical that the dangers of transportation offset the information the X-ray can afford.

Outside of other improvements, which, though in themselves brilliant, concern really not surgery but electrical technique, the exact localization of foreign bodies in three planes constitutes roentgenology's greatest offering. The methods devised for localization can in general be divided into two distinct groups:

the first localizes a foreign body by a depth measurement in a vertical direction below a skin mark; the other, in addition to a similar measurement, supplies also a surgical indicator. Ever since roentgenologists have been induced to supplement depth measurement from a skin mark by recording also the relation of the foreign body to a fixed anatomical land-mark, the surgeon's work has been greatly facilitated. As an example of the first, measurement only group, there may be mentioned the method which utilizes the principle of the parallax: given a plane surface, an object, and a movable light, the movement of the object's shadow on the plane surface will be proportionate to the distance of the object from the plane surface. With two such moving shadows the shadow of the object nearest the plane surface will move the more slowly. Using the foreign body to cast one shadow, a mobile rod on the apparatus is adjusted until its shadow has the same excursion as the other. From a scale the depth of the foreign body from the surface is computed and marked on the skin. In the other group the Hirtz compass is the most useful. This is an ingenious instrument of three parallel legs so adjustable to the irregular surface of the body that the base of the instrument preserves its level. The unique feature consists of an adjustable indicator swung from an arc that is firmly attached to the base of the instrument. The roentgenologist,

either by the fluoroscopic screen or photographic plate, then sets the instrument on the skin overlying the foreign body and so adjusts the indicator that it not only points directly toward the foreign body but if pushed into the tissues would impinge upon it at a depth marked on the indicator. He then marks on the skin the three points on which the legs rest and tightens all the adjustments, so that the legs and indicator are firmly fixed in their relative positions. The indicator is so constructed, however, that it can be swung the whole extent of its supporting arc without losing its sight line. As the entire apparatus can be sterilized it is simply handed to the surgeon who places its legs on the corresponding skin marks and follows the direction of the pointer to the foreign body. As the indicator can swing on its arc without losing its sight line it can always be so placed as not to interfere with the surgeon.

Fluoroscopy has also been developed to a point where its actual use in the operating room at the time of operation is perfectly feasible. Not only that, but the principle of stereoscopy successfully used for some time in roentgenology has been so applied that stereoscopic fluoroscopy is now possible. While the apparatus has had little more than a laboratory test, this was so successful that the invention promises soon to become of great value when it is desirable to operate under fluoroscopic control.

Regional Surgery.

When it comes to a survey of lessons learned that pertain to regional surgery it is found that outside the special application of general methods of wound treatment already described to meet regional requirements, little that is new has been gained. Be that as it may, however, the new conceptions of wound treatment are readily adaptable to all regions of the body and when utilized prove most efficient. Specialization in regional surgery had before the war been a recognized tendency that enabled certain men to become especially expert in limited fields. As the war progressed this tendency was fostered by the provision that every effort be made to segregate head wounds, for example, in special hospitals where they came under the care of surgeons specially fitted and trained to deal with them. Not only did patients thereby receive better treatment, but mortality tables were improved and opportunity presented for intensive study. At this point let it be emphasized once for all that what developments in regional surgery have appeared are confined strictly to traumatic lesions and that it by no means follows that the lessons learned apply equally well to the pathological conditions more frequently encountered in civil life.

Head.

The danger from early evacuation of operated head cases is perhaps greater than in

any other class of patients. It has been conclusively proved that delayed head operation is far preferable to prompt operation followed by immediate evacuation. Furthermore, undue haste in subjecting the patient to operation often proves to be a fatal error in judgment. For at least twenty-four hours after injury the brain is liable to be edematous and to extrude unduly if operated on in this interval; whereas delay allows not only absorption of the edema but also the formation of adhesions between dura and pia which lessen the liability of spreading infection over the brain surface. A slow pulse is a welcomed sign that recovery may follow and is not to be construed that operation is urgently needed, but rather is worth doing. Nor is it necessarily a sign of injurious compression demanding prompt relief; for it occurs with any wide exposure of the brain. And especially significant is the observation that a slow pulse, irrespective of the type of wound, means that the patient travels well. Moreover, immediate operation in many head cases is followed by an alarming drop in blood pressure. Yet the ever present danger of infection has to be reckoned with and the necessity for early operation on that score balanced against the advantages of delay. The immediate problem is mechanical and microbic and must be countered by mechanical and anti-microbic measures; the late problem is functional, frequently manifested only after a

lapse of time, and must be met by measures sometimes in direct opposition to those immediately indicated. Only the nicest judgment charts the safest middle course.

Some interesting and valuable data have been obtained from many repeated blood pressure determinations that have considerable diagnostic and prognostic significance. A compound fracture of the skull with the dura intact causes a high systolic reading; whereas a penetrated dura, provided there is free drainage, gives a low systolic pressure. Any wound involving the ventricles is accompanied by a high systolic level. By converse reasoning, therefore, blood pressure determinations offer a clue as to the nature and severity of cranial injury. Whatever the early behavior of the blood pressure it tends to become unstable, and when in that state constitutes a dangerous period for operation.

Depression of skull fragments is not the usual cause of symptoms and their immediate removal is not therefore to be undertaken rashly. Symptoms, paralytic and otherwise, are due not to depressed fractures but to destruction or commotion of brain matter not remediable by operation. As a general rule depressed fractures over the longitudinal sinus should in the first instance be left alone. A symptom syndrome comprising immediate spastic paralysis of the legs frequently associated with static paresis of the proximal segments of the arms, means occlusion of the

superior longitudinal sinus and of the veins that enter it by a depressed fracture of the vertex of the skull. Surgical intervention in such cases gave very unsatisfactory results, whereas rest alone effected many cures.

Osteoplastic flaps of scalp and bone probably constitute the best operative technique. The dura, if uninjured or inexpressive of underlying injury, should not be opened. Attempts to reach missiles or fragments deeply imbedded in the brain are not justifiable when the procedure results in further injury, for they cause little subsequent trouble unless heavy enough to compress the brain when the patient moves. Guilty weight is present when the fragment is seen to travel by gravity through brain tissue, a course of events readily disclosed by repeated X ray plates. Advantage may be taken of this tendency to travel. By placing the wound area most dependent fragments may later be shaken out along the original wound track. On the other hand the brain resents sooner or later the presence of any abnormality in its immediate coverings or in its substance. While some small lesions or foreign bodies in the brain have apparently caused no trouble, others equally unobtrusive have years later inaugurated intolerable inconvenience due to late effects on the brain. Because it is impossible to foretell their final effect every reasonable effort to remove foreign bodies and eliminate abnormalities should be prosecuted.

Above all, whenever operation is attempted it must never be stopped short of completion; palliative or incomplete operation is useless; let it be all or nothing. After all is said and done it is the strict application of the general principles of wound treatment, early operation, debridement even of pulped brain, and closure, that is in cranial injuries most responsible for the elimination of the destructive ravages of sepsis. Without these agencies even the most skilled brain surgeon would be unable to cope successfully with the infection of delicate brain tissue that so often proves rapidly lethal or not infrequently permanently disabling. In every instance the brain should be covered and drainage if indicated limited to the scalp only.

Much of the operative difficulty encountered in head work has been due to general anesthesia. Especially is this true in intracranial operations where intense vascular congestion invariably permits profuse venous bleeding that hampers and prolongs necessary procedures. While in isolated instances intracranial operations had been performed under local anesthesia as a necessity, experience of head teams during the war has made local anesthesia the anesthetic of choice. It has so few objections and so many advantages that it promises to become universal. Contrary to expectation the dura has been found to be insensitive to a marked degree except when twisted or stretched, and except at the

base of the skull where it is closely adherent to bone. The brain itself has long been known to be insensitive. A preliminary dose of a third of a grain of morphine thirty minutes before operation is routine except in the presence of marked intracranial pressure. The best anesthetic is a solution of procaine 0.5% to every ounce of which is added 15 minims of adrenalin, 1:10000. As much as six ounces of this solution have been used without causing toxic effects. Massive infiltration of tissues to be incised and a wait of at least fifteen minutes between injection and operation are indispensable factors for success. Extensive osteoplastic flaps and all decompression operations can be performed painlessly. The adrenalin proves such an efficient hemostatic that troublesome oozing is conspicuously absent, which not only adds to the surgeon's comfort but greatly shortens the length of the operation. Already current medical literature records instances of enthusiastic approval of local anesthesia for cranial operations, showing that the procedure is being eagerly welcomed and quickly adopted.

Spine.

The lack of experience and the absence of knowledge of the pathology of gun shot wounds of the spine led to a stagnation of effort in this region. In civil life there had been always a reluctance to tackle by surgical interference injuries of the spinal cord. This

reluctance is directly traceable to the observation that many times cases improve without operation in spite of abnormal conditions surrounding the cord; that in most instances cases operated either die or recover much as would have been their fate without operation; and finally that the technical difficulties of classical laminectomy, the loss of blood it entails and the doubtful results it affords, make operative measures too risky. War experience has done little to mitigate the objections.

Paraplegia, partial or complete, remains the diagnostic sign of cord injury. Three distinct types of paraplegia, however, are to be recognized: one in which the symptoms are due to local concussion; another in which the cord is organically severed; and a third in which paraplegia develops only after a lapse of time.

The paralyzing effects of local concussion are often marked, but usually begin to clear up within a few days. Slight local injuries, however, even when indirectly inflicted, are frequently associated with extensive edema, hemorrhage, softenings, and not infrequently with ascending cavity formation which may extend a considerable distance both above and below the level of the original injury. Such changes can obviously not be relieved by any reasonable operation; and the fact that, apart from secondary cavities that develop later, they occur immediately or within a very short time of the infliction of the injury, diminishes the favorable prospect of any surgical inter-

ference. When the track of the missile and X-ray plates rule out vertebral injury that might compress the cord the immediate onset of paraplegia is due solely to concussion. If, however, the symptoms fail to clear up as expected, the probabilities are that the later formation of blood clot has by compression of the cord perpetuated the paraplegia primarily due to the concussion whose effects have disappeared. In this comparatively small group of cases partial laminectomy for the removal of the clot is absolutely indicated. Not only is the operation the sole chance for permanent relief, but its results are brilliantly successful and marred by an insignificant mortality.

When the path of the missile demonstrates that paraplegia is due to organic division of the cord the case is hopeless. All operative interference is absolutely contra-indicated. Unfortunately complete transverse destruction of the cord is often very difficult of immediate determination. Even relatively slight injuries of the cord often produce for the first few days,—the very period when operation offers the best chance of success,—symptoms that may be confused with those of total and irreparable damage which contra-indicates operation. In such a dilemma there is some comfort to be derived from the observation that while the symptoms undoubtedly are in many instances largely or in part due to remediable compression of the cord by either a missile or fragment of depressed bone, the

immediate intra-spinal lesions due to concussion already exist and are irremediable by operation. Some clinical indication, therefore, of the severity of spinal injury is urgently necessary before operation can be reasonably undertaken. The safest guide is afforded by the form and character of the sensory disturbances, and especially by the changes and modifications in the reflexes of the affected limbs.

The type of paraplegia that develops only after a varying lapse of time is as a general rule the most favorable for operation. The paraplegia is due to compression either from the tardy formation of blood clot or from the displacement of a bone fragment caused during movement, or perhaps to both. In any event compression has been of short duration and permanent injury to the cord is therefore unlikely. If operation is performed immediately the results are uniformly brilliant.

Wider knowledge, therefore, has not greatly extended the scope of operative interference. The tendency is toward partial rather than classical laminectomy, and as in cranial work to favor local instead of general anesthesia. Increased confidence has been gained in the utility of placing muscle graft over an opening in the spinal membranes when leakage of cerebro-spinal fluid has complicated the operation; for an intact spinal dura has become of notable prognostic omen.

Chest.

Wounds of the chest had been seen a long time before surgeons recognized that such cases must be treated on principles which govern in other parts of the body. When so treated, with such modifications as the exigencies of the region demand, chest wounds need no longer show the frightful mortality formerly obtained. Success will not follow, however, unless it is appreciated that it is unnecessary actually to pierce the chest wall in order to cause intra-thoracic injury; for tangential wounds of the parieties only may be accompanied by intra-pleural damage almost as severe as though the missile had penetrated the chest wall or even traversed the lung. Worthy of equal consideration is the discovery that injury to the other lung by contra-coup is not at all uncommon, and is evidenced by subpleural and intra-pulmonary hemorrhages, large and small, that readily succumb to broncho-pneumonia. As in all wounds the immediate danger is from hemorrhage and shock; sepsis is the late peril. The immediate dangers, owing to the anatomy and physiology of the region, may be complicated and aggravated by the sudden or gradual formation of a pneumothorax.

The consequences of pneumothorax are by no means limited by the effects of collapse of that lung. Air in one pleural cavity, under ordinary atmospheric pressure, compresses

the opposite lung and displaces mediastinal structures toward the uninjured side. Suddenly created pneumothorax precipitates these changes so quickly that natural compensatory measures are for the moment inhibited. Respiration is immediately and seriously embarrassed. Rapid and labored respiratory efforts throw the mediastinal structures into unfamiliar oscillations or flutter that rapidly induces a state of pleural shock. Acting either alone or in conjunction with ordinary shock pleural shock is very quickly fatal.

Pneumothorax becomes, then, the immediately pressing factor to be considered in all chest wounds. The small penetrating wounds of rifle bullets are so promptly plugged by the instant collapse of surrounding soft tissues that pneumothorax is entirely prevented. Somewhat larger wounds, after slowly allowing partial pneumothorax to form, become effectually stopped with blood clot before the condition is complete, and its evil intents are thereby checked. Such wounds are almost never followed by any of the distressing symptoms incident to pneumothorax, and left alone do perfectly well when uncomplicated by hemorrhage or sepsis. It is always the large, gaping openings permitting immediate, complete, and persistent ingress of air, the so-called sucking wounds, that quickly induce all the attendent evils of pneumothorax. And yet if nature's efforts be promptly imitated and soft tissue, even skin alone, be so sutured

as to seal the pleural opening, much of the imminent danger is effectually eliminated. Wounds so lacerated as to prohibit closure by suture can be very satisfactorily sealed with an impervious dressing bound tightly to the chest. Needless to say prompt checking of the to and fro current of air lessens the inspiration through the wound of infected material that leads to subsequent pleural sepsis. Fortified by rest, and the administration of sedatives when indicated, cases so treated revive in a most astounding manner that enables them to cope successfully with later complicaions equally serious. Strange as it may seem, later operative pneumothorax is curiously less dangerous than formerly thought. Complicated pressure cabinets, both negative and positive, as well as intratracheal insufflation, all of which were devised to preserve lung expansion and prevent pneumothorax, have to a large exent been discarded as unnecessary. As a matter of fact an expanded lung constitutes a distinct difficulty in thoracic surgery, for only a collapsed lung can be palpated and manipulated at all nicely. Furthermore, pneumothorax is far from being an unmixed evil. The collapse of the lung that invariably ensues arrests by compression an otherwise often fatal pulmonary hemorrhage. With to and fro tide of air checked, the presence of pleural air becomes so beneficial in arresting bleeding that its loss by absorption must often be replaced artificially lest expansion of lung

stretch or displace the clot that occludes a torn pulmonary vessel. In fact, a deliberately produced artificial pneumothorax by injecting air through an aspirating needle may easily prove to be the forlorn-hope measure that arrests hemorrhage in a patient too exsanguinated to withstand a more radical procedure.

Chest injuries that do not succumb to shock, yet prove fatal within the first few hours, die of hemorrhage. Very often the two are so closely and interdependently related that they cannot be differentiated and death is due to shock-hemorrhage. As operation cures the latter but kills the former, decision is often agonizing. Be that as it may the proper attitude is to expect hemothorax in every chest wound and be prepared to deal with it. Blood in the pleural cavity is, like air, not entirely of evil import. It gradually arrests bleeding by compressing the lung that is lacerated, which is most desirable provided hemostasis occurs before the patient becomes exsanguinated. Once checked, the bleeding does not recur. Patients die more often from external hemorrhage in the wound than from intra-pleural. Hemoptysis in chest wounds is seldom fatal and secondary hemoptysis from that cause is very rare. Hemothorax, then, is not to be dealt with rashly. As a rule the profound shock that accompanies it serves sufficiently to contra-indicate radical operative measures. An attitude rather of keen watchfulness is to be taken. The level of the nipple is arbitrarily

assumed to be the upper limit of a hemothorax that does not threaten life by exsanguination. While hemothorax certainly checks pulmonary hemorrhage by compressing the injured lung, it may also compress the heart and opposite lung and by its massiveness prove fatal by asphyxiation. Mechanical interference with respiration, therefore, constitutes the only immediate indication for intervention which is best limited to aspiration of only enough blood to relieve the distress. If more is removed there is danger of secondary hemorrhage from lung expansion that tears away the clot from a torn vessel. If mechanical distress returns it is best not to repeat aspiration but to operate radically and check the hemorrhage. At the end of a week, however, if all goes well, danger of such secondary hemorrhage is eliminated, and it is best to aspirate freely in order to avoid the formation of adhesions which by preventing lung expansion court the onset of bronchopneumonia. Because of the sinister possibilities of adhesions it is permissible to aspirate the blood at any time and immediately replace it with air which just as effectually arrests bleeding and is not so liable to promote the formation of distorting adhesions. Furthermore, a hemothorax is very liable to infection which when it occurs runs the distressing course of an empyema. On the other hand, pneumothorax is more often accompanied by pulmonary infections, while a hemothorax

bears the brunt of infection and spares the compressed lung. It is only natural, therefore, that perfectly tenable differences of opinion exist as to the relative value and inocuousness of air and blood in the pleural cavity. Both accomplish the same purpose in the same way; each has its merits and faults that are to be nicely balanced in individual instances before a decision is made.

There are of course cases in which the laceration of intra-pleural structures is so extensive, and the resultant hemorrhage so profuse, that they are obviously hopeless. Such patients die within a very few minutes. Between these cases and those whose hemothorax for the moment at least is to be treated conservatively, there exists a large number of border-line cases requiring the keenest judgment. Immediate radical operation will save a surprising number of these. The wise surgeon stands ready to interfere the moment he is convinced from the patients behavior that conservative methods are failing to check the hemorrhage. Local anesthesia is the method of choice. The chest is to be opened widely by subperiosteal resection of the fourth rib from the junction of bone and cartilage posteriorly for six or seven inches, followed by incision of the pleura through the periosteal bed. This approach gives the best exposure and should be chosen irrespective of the location of the injury unless the latter offers approximately as favorable a site. Strip the

periosteum and pleura carefully from the posterior surfaces of the adjacent ribs above and below, when it will be easily feasible by suitable retractors to spread the wound sufficiently wide to permit free entrance of the surgeon's hand. Through this wound the collapsed lung can be easily delivered and freely palpated. Pulse and respiration are not at all seriously affected if the lung is handled gently. Wounds of the diaphragm are first attended to, and through the rent any abdominal measure that is indicated should be quickly performed, enlarging the diaphragmatic wound if necessary. Shell fragments, bone splinters, and bits of other foreign material are a serious menace and must be removed even though fresh incision into the lung be necessary. All wounds in pulmonary tissue must be treated by thorough debridement and firmly sutured, not only to control hemorrhage, but also to remove contamination and protect the adjacent pleura which is less resistant to infection. It is surprising how well the elastic lung lends itself to suture without tearing. Mediastinal missiles are to be left alone. Attempts at their removal are surely followed by disaster, for mediastinal structures are strangely adverse to manipulation. After gently wiping the pleural cavity clean of free and clotted blood suture the wound in the pleura, very accurately everting the edges in order to bring serous surfaces smoothly together. It is at this stage that the value of placing the inci-

sion in the periosteal bed is appreciated, for the fibrous periosteum prevents the sutures from tearing through the delicate pleura. Drainage should never be carried into the pleural cavity but only down to the sutured serous membrane. The last step is the aspiration of intra-pleural air in order to stimulate lung expansion and prevent distorting adhesions. After operation patients are kept in a semi-upright position, given morphine judiciously, and never transported under eight days.

However managed, all chest injuries are sooner or later liable to infection. The lesions vary from broncho-pneumonia, abscess, and gangrene of the lung to massive empyemata. Anaerobic infection of hemothorax is common, about 10%, and is most frequently due to the *bacillus Welchii* and *bacillus sporogenes*. Jaundice, especially if associated with epistaxis, is an index of a very severe type of infection with anaerobes. The war has added little that is new to operative measures for dealing with all such late complications, but post-operative care has been, especially for empyema, completely revolutionized. The immediate application of Carrel-Dakin technique to this affection has made the care of such cases a pleasure to all concerned. Through the operative drainage wound Carrel tubes are inserted towards the apex of the lung, into the axilla, across the diaphragm, and down into the posterior costo-phrenic space. Regular

instillations of Dakin's solution quickly checks purulent discharge, obliterates all odor, and promptly institutes a marvelous improvement in the patients' general condition.. Occasionally a broncho-pleural communication sucks Dakin's solution into the throat with most distressing symptoms, but generally a change in posture or more gentle instillation overcomes the difficulty. In time bacterial count of the secretion demonstrates sterilization of the cavity. The tubes are then withdrawn and the wound sealed with an impervious dressing when healing usually takes place. X ray plates of the failures, after the sinus has been infected with barium, show either necrosis of rib, a pleural pocket with a small track leading to the main sinus, or, which is not at all uncommon and very important, an isolated collection of pus totally independent of the main lesion. Under appropriate treatment all but a very few such cases can be completely healed.

Empyema.

It is only biased enthusiasts who still maintain that empyemata are always cured quicker and surer by Carrel-Dakin treatment than by any other method. First reports of cases so treated, it is true, showed marvelously quick sterilization of cavities amply proved by bacterial count and culture control. The wounds were, therefore, closed by secondary suture and the patients discharged as cured, only to

develop weeks later symptoms which on investigation denoted persistent pleural sepsis that only further operative treatment eradicated. When it is remembered that the Carrel-Dakin technique as applied to empyemata transgresses all the surgical principles that are vehemently stressed as essential fore-runners of its success, it is not so surprising that the method sometimes fails completely, and not infrequently proves to be no quicker nor surer than other methods. An empyema is essentially a bottle shaped cavity half of whose walls are rigid and the other half equally impossible of collapse. Carrel-Dakin technique cannot accomplish its marvelous results in such a cavity wherever situated, and should not be expected to. It is solely because of these ineradicable limitations that Carrel-Dakin treatment has been somewhat disappointing in empyema. What it does accomplish, however, in these cases that is distinctly worth while, is promptly and markedly to lessen the discharge; is to keep the patient smelling sweet and clean; is to make the dressings easy; and is to improve the patients' general condition more quickly and more noticeably than does any other method of treatment.

The influenza epidemic with its high incidence of complicating empyema aroused exorbitant hopes that at last through sheer experience with vast numbers definite conclusions regarding the proper management of pyothorax would be established. Not only

were expectations dashed, but only recently has any order begun to emerge from the chaos into which the whole subject was thrown by the combative adherents of early and late operation. As the two camps were about equally divided, published equally favorable statistics, and later admitted respective statistical fallacies that exactly offset each other and preserved relative equilibrium, confusion was further confounded. Gradually a semblance of order is being restored by mutual concessions compelled by irrefutable facts. In influenza pleural effusion develops early and massively. At first the effusion is serous and becomes purulent only after it has persisted for a week or ten days. Cases that are fatal in the period of developing pleural effusion die, not from the effusion, but from the concurrent pulmonary process, except when by its massiveness the former mechanically embarrasses cardiac and respiratory action. Conservative management of influenzal pleural effusion compels an attitude of non-interference until signs of cardiac or respiratory difficulty supervene, when intervention is to be limited to the aspiration of sufficient fluid to afford relief. With a return of embarrassment aspiration can be safely repeated as often as necessary and a fair percentage of cases will by this means alone escape a frank empyema and recover. Not until the fluid is purulent should operation be undertaken. As a rule, by the time the effusion has become purulent,

the pulmonary process has so far subsided that operation does not entail further risk on that score. Unfortunately, opinion is about equally divided between the merits of closed or open operation with or without Carrel-Dakin treatment, and mortality and morbidity statistics fail definitely to settle the dispute. The probabilities are that both methods are equally good and that the choice of method resolves itself into individual preference and ease of after care.

Abdomen.

An expectant attitude in regard to abdominal wounds held longer than it should have solely because of inadequate provisions for early operation. Experience gained in the war fully confirmed the opinion long held that abdominal trauma, whether penetrating or not, demands in the presence of any sign of internal injury immediate exploration. Clean-cut, small, penetrating wounds made by high velocity bullets are no exception; for such missiles however innocuous in other regions raise havoc with hollow abdominal viscera. The necessary operative technique for dealing with traumatic lesions of the abdomen was with very slight adaptations copied directly from that already practiced in civil life, and experience of general surgeons in the war has added little of importance in the way of technique. There is noted a tendency to use fewer suture lines in gastro-intestinal work;

but this was doubtless practiced for the sake solely of speed in operating and will probably not prevail. Nevertheless, the experience demonstrated the security of even one suture line when time was at a premium. End to end anastomosis has gained a preference over lateral now that the fear of leakage at the mesenteric angle has been once for all dispelled. Abdominal drainage as usually practiced proved even less effective than suspected. No new ideas were offered for the management of peritonitis; and the sheet anchor against infection in all other regions, Carrel-Dakin technique, is strictly contra-indicated in the abdomen where Dakin's solution causes gross mesenteric hemorrhages and dissolution. Intra-peritoneal wounds of the bladder may be safely sutured without suprapubic drainage of that viscus, but extra-peritoneal wounds must be drained.

Abdominal tenderness some distance from the wound denotes probable intra-peritoneal injury. Protruding omentum is not in itself particularly dangerous but is an infallible indication for operation because it signifies visceral injury. Wounds of the chest, back, and buttock, not directly involving the abdomen, may cause retro-peritoneal hematomata that closely simulate symptoms of intra-abdominal injury. Passage of flatus after injury negatives lesions in the large gut, especially the descending colon. Distension of wounded hollow viscera does not rule out a wound of

exit. Antero-posterior wounds are attended with a higher percentage of recovery than are oblique, transverse, or vertical wounds; and wounds of the lateral abdomen are less grave than median. Abdominal injuries complicated by wounds of the buttock always do badly.

Blood Vessels.

As a rule, wounds of blood vessels, large enough to permit of operative surgery, proved so immediately fatal that little opportunity was presented for the development of this branch of surgery. And when the patients survived the initial hemorrhage, the nature and extent of the wound held the severed ends of the vessel too far apart to admit of immediate repair. The use of Tuffier's tubes in such contingencies very often tided over the critical period when adequate collateral circulation was being established. The tubes generally become occluded with blood clot in from twenty-four to seventy-two hours and should be removed as soon as pulsation in the vessel distal to the wound has ceased.

With complete division of a main arterial trunk and failure of collateral circulation the definite line of demarcation seen in civil practice marking the line of gangrene was curiously missing in war wounds. Site for amputation had to be determined, therefore, by noting the place where the limb was cold and discolored and where capillary circulation was

active as shown by the return of blush after the blanch of pressure. Moreover, arrest of blood current at a point considered favorable for ligature in civil practice was often followed by gangrene when the arrest was due to gun-shot injury. Even small perforating wounds without muscle or bone laceration were unhappily followed by such sequelae. The popliteal and both tibials stand out as arteries injuries of which are especially dangerous to the vitality of the limb.

Lateral wounds of vessel walls lacerate the adventitia and media only at the site of the lesion, but in the intima lacerations radiate for considerable distances up and down the vessels. The rarest condition is found in what are known as dry wounds, in which a small arterial perforation is quickly plugged by a clot held in position by perivascular tissue. Spontaneous hemostasis occurs and rapid aseptic healing usually follows. Wounds that are dry for eight to ten hours, however, may then bleed and give rise to the first intimation of vascular injury.

A much more common condition is diffuse hematoma. The peri-vascular tissues fail to hold and blood is extravasated until its tension equals blood pressure. Further bleeding is then checked spontaneously and a visible tumor appears when the vessel is superficial; a diffuse swelling when it is deep. The tumor mass undergoes either complete organization and absorption, or its center, subjected to ar-

terial pulsation, softens and disintegrates while its periphery hardens and forms the sac of an aneurysm. If the adjacent vein was injured at the same time the combined organization and disintegration results in an arteriovenous aneurysm. In all hematomata and aneurysms the immediate branches of the main artery are often concurrently involved and prevent the establishment of a collateral circulation that would otherwise save the limb.

Absence of pulsation distal to vascular injury is not a safe criterion of permanent occlusion, for the vessel may be only temporarily plugged by a clot due merely to contusion from direct impact without laceration. The lesion is the result essentially of an undue stretching, locally of the intima only; locally of intima and media; or circularly of intima and media around the entire circumference of the vessel. The first is almost symptomless; the second is recognized by distant emboli denoting thrombosis in the injured vessel; and the third is detected by the fusiform dilatation with invariable and extensive thrombosis.

All hematomata should be evacuated and the cavity cleaned by debridement. The management of the wounded artery itself must be adapted to circumstances. Ligation is the simplest, quickest, and generally the best. When done, the vein as well must be tied. In as much as ligation of a main artery in the presence of a hematoma is followed by

partial or complete necrobiosis in one third of the cases, it is well before ligating to test the efficiency of collateral circulation. Under temporary compression a small incision as distally as possible should bleed; the distal end of the compressed main vein should fill; and blood should escape from the distal end of the wounded main artery. If these signs fail collateral circulation is not dependable and vascular suture or amputation must be chosen.

Paralyses, independent of concomitant nerve lesions, may follow arterial injury and are not in all instances by any means creditably accounted for as types of Volkmann's ischemic paralysis. They are rather of reflex origin, not inaptly named angiotic paralyses, and unlike Volkmann's often recover. They follow arterial injury that does not effect complete blockade of the vessel, and are characterized by a flaccid muscular paralysis distally, with a wide spread loss of cutaneous sensibility that extends even above the wound. The affection has been successfully treated by excision of the sympathetic nerves that course the sheath of the injured artery, periarterial sympathectomy. The muscles have in 50% of the cases regained their tone and power, not always at once but eventually. The operation is followed by arterial contraction for the first ten to twelve hours when a reaction sets in that results in vasodilation which is more or less permanent. This vasomotor sequence is

perhaps worthy of pertinent consideration as a possible explanation of tardy hemorrhage in the so-called dry wounds of arteries.

Peripheral Nerves.

Of all the surgical specialities none has had graver problems in diagnosis and therapy than those that fell to the lot of neurological surgeons. It is unhappily true that most of the moot points, vital as they are, must wait still longer before certain judgment can be pronounced. Prognosis remains especially uncertain. Why, for example, 60% of nerve lesions recover spontaneously with postural, mechanical, and electric treatment and 40%, though apparently no more serious, do not, cannot yet be explained. Because a nerve fiber is incapable of stimulation does not mean that it is not in a condition of possible spontaneous regeneration. Injured nerves exhibit such a surprising tendency to recover in time that it is always safe to defer reparative operation for a month where soft parts only are involved; for two to three months where bones are implicated; and indefinitely as long as progress toward recovery is shown.

Nerves withstand infection remarkably well. They should, therefore, when divided, be united at the first deliberate operation irrespective of the condition of the wound. Fifteen inches of nerve may be stripped without fatally destroying its capillary circulation. The severed ends should be approximated

with interrupted sutures that pass only through the sheath and that do not twist the nerve. As union of nerve structure is well advanced in four days, cat-gut is the suture material of choice. Always lay the sutured nerve in healthy tissue, preferably muscle, as far from the site of the later scar as possible. Fascia, fat, or other tissue tubes wrapped around the nerve are of questionable value and may be harmful by constricting the nerve and inhibiting new blood supply. Transplantation of one nerve into another is much less effective than tendon transfer. From six to eight weeks is required for firm healing of a nerve, during all of which time it must be protected from the slightest stretching.

Late operation for nerve injury is indicated, for complete division of a trunk; incomplete division when progress toward recovery ceases; and for severe neuralgic pain. The last named indication has received considerable attention because of its frequency and because of a better understanding of the causes of the pain. Outside of those cases where nerve trunks are caught and pinched in scar tissue, pain in injured nerves and their distribution is due to neuromata. A neuroma is merely an over-growth of nerve fibers outside the sheath and represents nature's perverted efforts of axis cylinder extension. Neuromata are central, lateral, or terminal, depending on the nature and site of the original wound of the nerve. Wherever

found neuromata are to be widely excised, sectioning nerve structure until no further scar tissue is found.

For complete division of a nerve trunk the earliest prudent occasion must be chosen for operation. Delay until concommitant wounds of bone and soft parts are long healed is not only justifiable but should be the rule. It is especially in regions deprived of innervation that bacteria survive latently for long periods only to jump into virulent activity when disturbed. Throughout the interval of waiting, however, every means of massage, electricity, and hydro-therapy should be constantly invoked to prevent contractures and to preserve suppleness of joints and muscles to the end that the nerve may later have healthy tissues to innervate.

The cases showing incomplete division of nerve trunks call for the most deliberate judgment. Many of these cases recover spontaneously, though periods of arrested progress are not infrequently most disquieting and confusing. There is often, not actual anatomical interruption of conductivity, but merely a physiological one. Differentiation is at times exceedingly difficult, usually impossible without repeated painstaking examinations; but as a rule in physiological interruption muscle tone is more often preserved than not. The lesion in physiological interruption is frequently extra-neural due to compression by scar, bone, or foreign body, without definite

destruction of neurons until pressure has been long maintained. On the other hand the lesion may be the result of a simple contusion without laceration, causing either an intra-neural hemorrhage or merely a localized edema, both of which through compression of neurons give rise to physiological non-conductivity. All such intra-neural lesions tend to recover without permanent destruction of nerve fibers. Whether physiological interruption is due to extra-neural or intra-neural causes is most difficult of decision; and as time goes on decision becomes urgent because, if extra-neural conditions persist, they may easily cause irreparable and permanent damage, while intra-neural lesions tend to improve spontaneously by absorption of exudate, and almost never grow worse. When in doubt and decision presses, it is always justifiable to cut down on the nerve and determine conditions by actual inspection which is a tolerably safe guide.

Trench Foot.

There has come out of the war a new disease, trench foot, which lies somewhere between chilblain and frost-bite, and is characterized by painful anesthesia, edema, phlyctenules, gangrene, and sloughing. It follows exposure to wet and cold, not necessarily freezing, and is aggravated by inactivity, cramped posture, and tight boots. Mild cases complain of numbness, cold, pain, and tender-

ness of a burning tingling character most marked at points of greatest pressure such as the heel and ball of the foot. The part affected shows discoloration varying from slight hyperemia to purple; and anesthesia to touch and pin prick. Moderate cases have in addition severe pain on exposure to heat and on motion of the joints in the affected region. The most severe types show also blebs, edema, and local gangrene.

Differential diagnosis is concerned only with chilblain and frost-bite. The former is accompanied by intolerable itching; the latter occurs more often in very cold dry weather and shows more massive destruction.

Treatment is prophylactic and symptomatic. Adequate protection from cold and wet is primarily essential. The most comfortable and effective dressing is a powder composed of boric acid and camphor. Whether definite skin lesions are present or not, antitetanic serum should always be given in prophylactic doses. Radical intervention is strictly tabooed; all that is required is patience until spontaneous separation of the slough and nice demarcation of the line of gangrene occur, when the obviously devitalized tissues may be trimmed away. Convalescence is prolonged and some permanent disability is not so very infrequent.

Burns.

There seems to be a wide spread feeling that the war has revolutionized the treatment

of burns, which is entirely erroneous. Newspaper exploitation of a new remedy credited with exorbitant journalistic virtues is alone responsible for the feeling. The truth of the matter is that the importance of treating burns as aseptically as are all other wounds was so emphasized that much of the credit usurped by paraffine mixtures rightly belongs to asepsis. Nevertheless, there is much virtue in these various mixtures which, irrespective of other ingredients, are essentially paraffines of low melting point. They are applied directly to the burned surface, either painted on with a camel's hair brush or sprayed on from a special atomizer, when the mixtures immediately harden. The only further requirement is a few layers of gauze. These paraffines form perfect protective dressings as painless in their removal as in their application. Beneath them fine healthy granulations rapidly appear with no tendency toward exuberancy. Epidermization is swift, and the terminal scar is soft and pliable pleasingly free from annoying contractures. As a matter of fact, however, the share of credit that redounds to paraffine mixtures is by no means exclusive; for equally as effective, painless, and satisfactory a remedy for burns is found in dichloramine T. Furthermore, the latter has antiseptic properties that paraffine mixtures lack which adds a welcomed sense of security.

Physio-therapy.

Probably never before has the value of

physio-therapy been so generally appreciated. Men well versed in the use of heat, light, baths, massage, and electricity have ably and conclusively demonstrated the invaluable efficacy of these agents when scientifically and persistently employed. Through their untiring zeal and efforts many a joint has been spared disability; many a contracture has been prevented; many a nerve has had its conductivity restored; and many a painful convalescence has been agreeably shortened. No longer can surgeons dismiss as cured fractures whose union is firm and whose soft parts are healed with the complacent remark that only time and use will restore perfect function. Far too often in the past, however, function has never fully returned because the surgeon's interest in the cases ceased with anatomic repair and there was no one to supervise functional convalescence. Perhaps the fault does not lie wholly with the surgeons. Very often patients themselves have been so satisfied with anatomic repair and vague assurances as to the future, that they wilfully or ignorantly forewent prolonged after-treatment. Wounded soldiers, on the other hand, were under orders and, willing or not, had to submit to extended treatment. Doubtless this ability to control patients was a very essential factor in the success of physio-therapy; but lack of this control is not an excuse, but merely an explanation of failures in civil life. And the explanation offers the remedy. Now that surgeons have been brought to appreciate the value and neces-

sity of physio-therapeutic after care, laymen must through a campaign of education be likewise taught not only to recognize the value of such measures but also to demand that they be given the benefit of them.

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